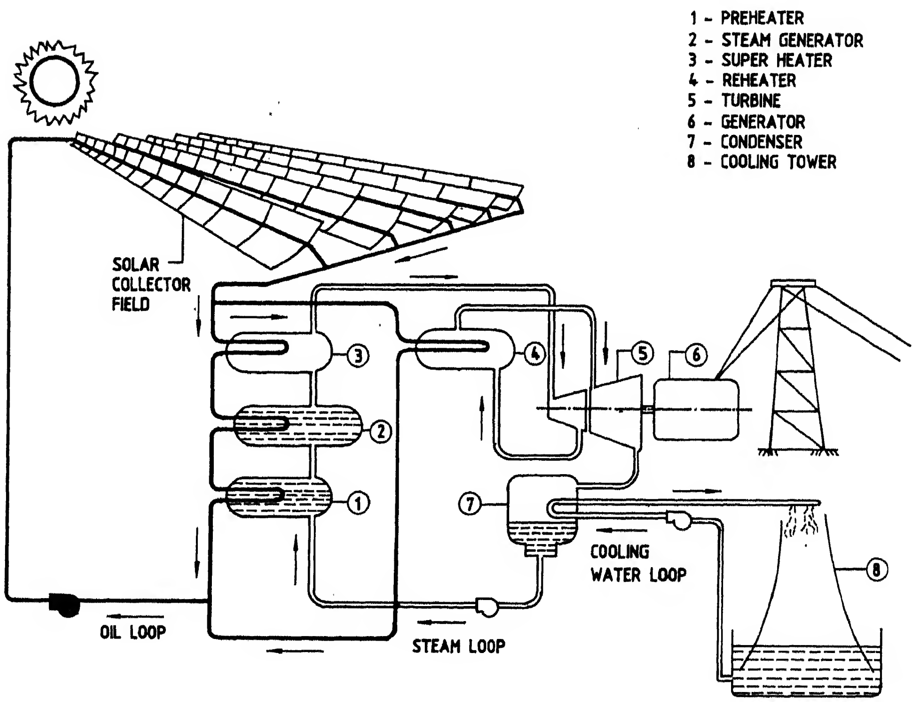
ENERGY OPTIONS FOR INDIA

(SEMINAR PROCEEDINGS)



INDIAN NATIONAL SCIENCE ACADEMY, NEW DELHI

ENERGY OPTIONS FOR INDIA

(SEMINAR PROCEEDINGS)

Guest Editors
R. CHIDAMBARAM
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INDIAN NATIONAL SCIENCE ACADEMY

Indian National Science Academy, New Delhi

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First published April, 1993

Price : Rs. 60/- US $ 20/-

Printed and published by *S K Sahni,* Executive Secretary, Indian National Science Academy on behalf of the Academy and printed at *Aakriti Graphics,* New Delhi. ✆ 5700089

PREFACE

A seminar on Energy Options for INDIA was held on April 10, 1991 in New Delhi under the aegis of the Indian National Science Academy. Experts on electricity generation from various energy sources gathered together to share view on their present perceptions and on possible future strategies for the energy scenario in our country and discussed different aspects like the available resources, constraints, environmental concerns and so on.

The seminar was convened by Dr. R. Chidambaram, Director, Bhabha Atomic Research Centre. Professor P.N. Tandon, President, Indian National Science Academy, inaugurated the seminar. The invited speakers included Shri J.K. Bhasin, Chairman, Central Electricity Authority, Shri B.V. Chitnis, Vice-chairman, Tata Consulting Engineers, Professor S.P. Sukhatme, Indian Institute of Technology, Bombay, Shri T.R. Satish Chandran, Director, Institute for Social Change, Bangalore, Shri Anil Kakodkar, Director, Reactor Design and Development Group, Bhabha Atomic Research Centre. There was a lively discussion with some major presentations by Brig. M.R. Narayanan, Chairman and Managing Director, Central Electronics Limited, Sahibabad, U.P. and by Dr. S. Varadarajan, Vice-President, INSA.

Manuscripts of only some of the presentations were available. Transcripts were, therefore, prepared from the recorded talks. The discussion part of the seminar had to be entirely retrieved from the tape. In the process, some names, some words could not be deciphered. Even so attempts have been made to include the discussions in their entirety. The result is before you, the proceedings of the one day seminar on Energy Options for India.

Efforts of Dr. V.K. Jain of BARC in preparation of the manuscript of proceedings are gratefully acknowledged.

Dated : April, 1993

BLS Prakasa Rao
Editor of Publications, INSA

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INAUGURAL ADDRESS

P. N. Tandon
President, Indian National Science Academy

As President of the Indian National Science Academy, it is my privilege to welcome you all here this afternoon. As you are aware, it was decided to utilise the occasion when Fellows of the Academy get together at one place, to discuss some matters of general interest. We have been conscious of the fact that the Academy should be involved in a significant way with the problems that face either science or the society in this country. So we just tried to make a small beginning in this direction and as a result, we have this occasion when so many of you are here to take up one such subject for discussion. We are deeply conscious of the importance of time that you have to spare for the Academy. We are also conscious of the fact that you are going to have a hectic two-day programme. Inspite of that, we crave your indulgence and thank you for spending a little extra time to be able to increase the activities of the Academy and certainly bring them more in line with its objectives which were laid down by the founding fathers.

Among the major problems that face this country, I, as an individual, see three major ones; there are very many, of course, which you are all aware of. But I consider population explosion problem, problem of food and nutrition and problem of energy as three major scourges that face us in this country, where we all know and sincerely believe, science and technology can make a major impact. Of course, population is a more complex issue involving a lot more and also social components which are needed to be discussed. We should not feel shy of discussing such problems even if we have to take help from our friends from other disciplines. Food, we have discussed on a number of occasions and only one thing we can say very proudly is that as a result of the contribution of science there is improvement in the food situation though there is nothing to be complacent about.

An area which several agencies have been looking at is the energy scenario in this country. Diverse groups such as Planning Commission, Ministry of Science & Technology, Ministry of Energy, etc., are engaged in this effort. Therefore, when the Council decided to take this up as a subject for discussion, we requested Dr. R. Chidambaram to organise this afternoon's session. I think we could find no better person to do so and I am happy and grateful to Dr. Chidambaram for having accepted this request of the Council. We

are also deeply conscious of the fact that half a day is too limited a time to discuss such a vital matter. Dr. Varadarajan, while talking to me said, we should have appropriate time for greater discussion in much greater depth. We will certainly try to do so. But, we have to take some initiative and this is the way for greater interaction with other colleagues and to see if we could produce a document for future consideration. Let us study and discuss the pros and cons of various options available to us and it was with this intention that we approached Dr. R. Chidambaram and gave him this responsibility for the symposium. As you will see, considering all the limitations of time, he has been able to gather together very outstanding people deeply involved in this area. I hope that either immediately after this symposium or shortly after that, if necessary with a more indepth discussion among a group of people, if we could produce a document, this will be a step in the right direction and one of the steps towards fulfilling the objectives of the Academy. Thank you very much.

Dr. Chidambaram, I hand this over to you now.

INTRODUCTION TO THE THEME OF THE SEMINAR

Dr. R. Chidambaram, FNA
Director, Bhabha Atomic Research Centre, Bombay - 400 085

Professor Tandon, Distinguished Fellows of the Indian National Science Academy, other distinguished persons present, ladies and gentlemen : I am very grateful to INSA and Professor Tandon for giving me this opportunity to organise a half-day seminar on energy options for India. Among the problems that are facing this country, surely one of the biggest problems is the shortage of energy. There is no question that consumption of energy per capita or the consumption of electricity per capita is one of the surest indicators for the standard of living in a country and in this regard I am sorry, I have to start with a depressing projection. (Fig.1) We are very badly off if we

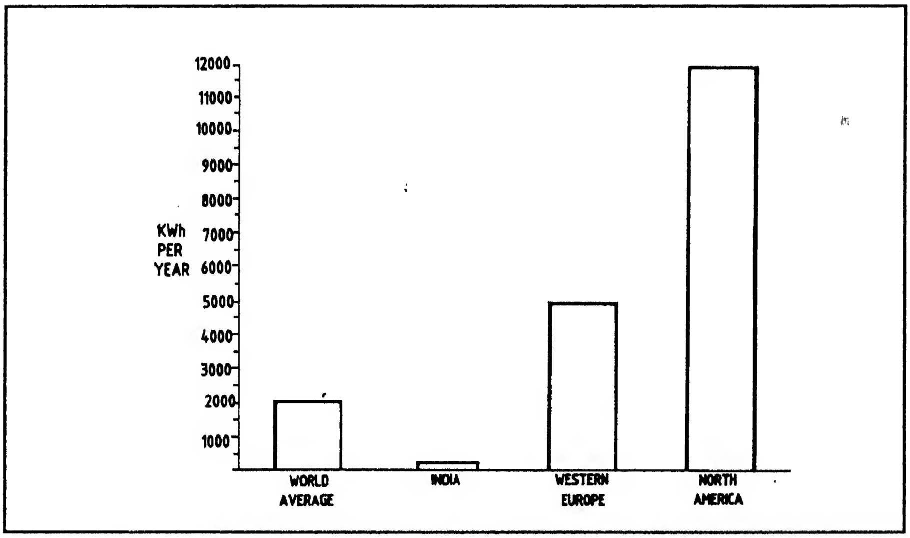


Fig. 1. Per Capita Consumption of Electricity

look at the per capita consumption of electricity at present and compare it with western Europe or the USA. Whatever lifestyle you assume in the future, the increase of or inputting of more energy into the Indian system will surely improve the standard of living. There are many ways of looking at it and I am sure speakers who follow me will talk of this. But I will focus on one or two broad indicators. The correlation between the per capita GNP and the per capita electricity consumption, (Fig.2), tends to be linear, until luxury or very conspicuous consumption starts. If we look at other parameters, some of which may not be so obvious e.g.life expectancy at birth,

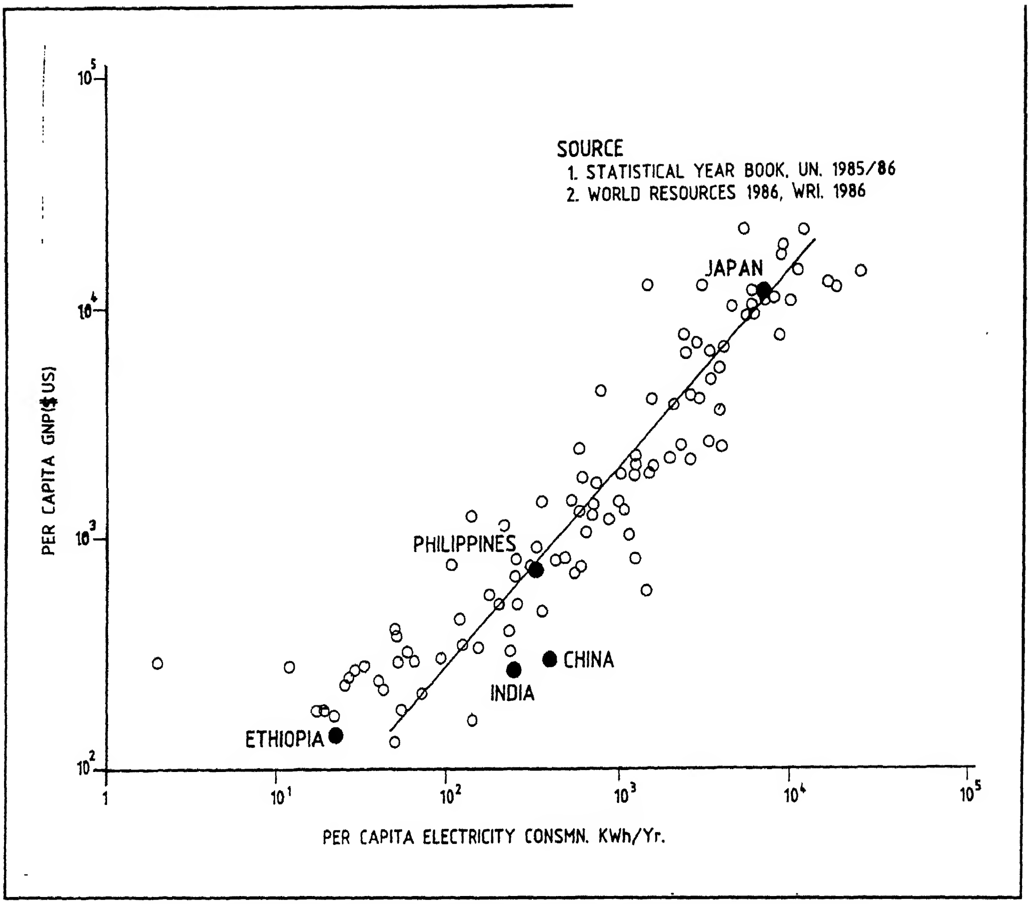


Fig. 2. Comparison of GNP with Per Capita Consumption of Electricity

and plot it against per capita consumption, we get a S-shaped curve with two kinds of saturations, (Fig.3). The lower one I think is related to the fact that once you are born and once major diseases have been eliminated from the world there is a certain minimum life expectancy. The second one is related to the fact that beyond a certain stage the human system tends to fail and perhaps increase of electricity consumption at that point of time does not increase life expectancy much further. We must also remember that even though our per capita electricity consumption is around 250 kwh, all of us in this hall for instance are surely consuming may be 5-10 times more. We are somewhere higher up on this curve — on an average and this consumption in my opinion is limited, for example at least in my case, by my ability to pay my electricity bills. May be I would consume a little more if I could afford it, and if I could afford to add more domestic gadgets for my use. The poorer part of the country, therefore, is the one likely to

gain more by increasing electricity production now by whatever method this is done.

Now among the major sources of electricity production in the country, we have hydel, of which you will be hearing shortly, and that of course is the best; it is clean and it is renewable. Then we have coal and we have nuclear. We have separate talks on these so that we hear perceptions by

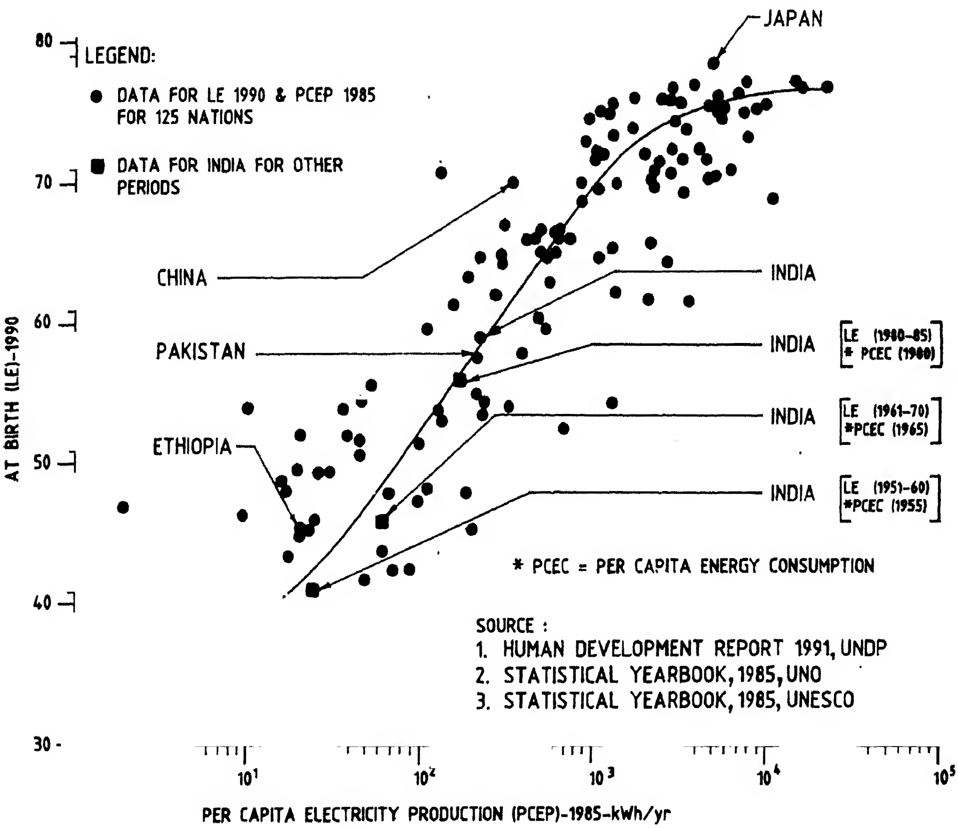


Fig. 3. Comparison of Life Expectancy at Birth with Per Capita Electricity Production

various specialists on these topics. The amount of coal that we have will perhaps last us for 150 years and this is not a very long period in a nation's history. And this coal is also not of very good quality. There is a lot of ash in it and the coal has got other uses apart from burning for production of electricity. We have uranium, a limited amount of uranium which may last for 30 to 35 years if we use it in the pressurised heavy water reactors. If we go in for fast breeder reactors it may last much longer and with a

material like thorium, of which we have 5 times as much as uranium, and we go in for the U-233 fuel cycle the nuclear fuel in this country will probably last very much longer. Then, there are renewable energy sources such as bio-mass, solar, wind and some others. Work is going on in this country on harnessing all these resources and about which you will be hearing.

What are the imponderables that we have to consider, including external factors, as we plan our energy system? We have seen how one incident in the middle east almost completely ruined our energy economy—in fact the whole economy due to factors like increase in the price of oil which shot upto $50 a barrel. These are real life situations and we have to guard against them. We must have energy systems available in this country which protect us to a large extent from these fluctuations.

Things could change if new technologies appear on the scene. It is quite possible that by the middle of the next century fusion may become feasible and if it happens, the feeling is that it may be an inexhaustible source of energy. But really, what we are talking about today is : What should be our strategy for the next 25-30 years? What should be our energy strategy, while keeping in mind other things that may happen over a much longer period? Right now all of us are suffering from resource constraints. So, even if the technology and the qualified man-power are available, we may be running short of money to build these energy systems, and we have also to consider this.

I have requested the speakers here to include the environmental impact of energy systems in their talks. In fact I had planned to have an independent talk on this subject but unfortunately the two people who could have spoken well on this issue and whom I had invited are not available. On the other hand, there are not many people who have a comprehensive understanding of the environmental impact of all energy systems. So I have requested speakers on specific topics to cover as much as possible the environmental impact of that particular energy system. But I am afraid this is going to be a lacuna in today's proceedings. In a nutshell any kind of energy system that we take will have some effect on the environment. But I do not think there is any technology which is a zero risk technology and so also there is no technology with zero environmental impact. If we build a hydel system we displace people, disturb the ecology of large areas required for storing large quantities of water. If we take a coal based system or any fossil-fuel based system, we do produce gaseous pollution, comprising of oxides of nitrogen, sulphur and of course carbon dioxide. There is a great deal of global concern

about the so-called greenhouse effect, the increased production of carbon dioxide in the atmosphere which prevents infrared radiation reflected from the earth to go out and the consequent possible increase in the temperature of the earth. There are pessimistic views — not that all people believe in it — that this kind of greenhouse effect over a few decades may raise the temperature of the earth by 3 deg. C or so in which case you will have melting of ice at the polar caps, followed by disastrous consequences. Really there is no clear cut scientific evidence that this is taking place or will take place and this is still a matter of debate. Among the countries the developed world is worried about are China and India, where electricity production is largely from coal and if this goes up very rapidly, then there are possibilities that the contribution from our side to the positive greenhouse effect will also go up.

The other question that one has to ask is, "Suppose we do not produce more energy, what is the effect of that?" The lack of this energy is also going to affect all of us as was evident from the correlations I mentioned between energy use and any parameter like gross national product per capita or public health or anything like that. Nonavailability of energy will also have an impact on the environment and human health. So when we discuss about our environmental concerns, which are very genuine, we have to worry about the effect on the environment that nonavailability of energy will have. We take the case of nuclear energy, which will be discussed in one of the talks. The effect on the environment, as long as the reactor works safely, is very little. If we talk of general safety the risk from living two or three years near a nuclear reactor may be something like travelling 100km by car on any Indian road. But really what people are worried about is not this effect, but the drastic effects a possible nuclear accident may have on the environment as happened in Chernobyl. Chernobyl was an accident that should not have occurred if proper procedures had been followed.

There is concern about the management of radioactive waste that we produce in nuclear reactors. But the people who work in this area are convinced that they have the know-how and the technology to run and operate the reactors safely and to dispose off the radioactive waste without affecting the environment.

I have also requested the speakers to talk on the role of energy conservation because that is something very important and anything that is wasted particularly in an energy starved country like India is criminal. I am sure there will also be some discussion on fuel and energy efficient systems. There

remain two important questions and these are the questions probably we should summarise in the final document that Professor Tandon said will be produced on behalf of Indian National Science Academy. What should be our energy strategy over the next 25-30 years? Keeping in mind the gestation periods for deployment of new energy technologies, how do we shape our technology development policies related to electricity generation and how will it help us to go through the next several decades? The other questions which perhaps one should discuss are, "Should we develop an optimum energy mix taking into account all our resource constraints, technological factors, ecological factors, and cost of electricity production by various methods? Is there any other option considering the situation as it exists in this country? Should we maximise output in this mixed energy system subject to resource and technological constraints?"

An INSA document dealing with such questions should be useful to the Government in framing its energy policy. India desperately needs energy and I remember the statement of Dr. Bhabha in the olden days who used to say "There is no energy as costly as no energy !" So, no power producing system can be costlier than the loss to the economy caused by lack of adequate power. These are the types of questions, which I have requested the very distinguished panel of speakers we have here, to talk about. They have different perceptions of this subject based on their differing backgrounds. I am requesting them to speak for 20 minutes each and we shall have a discussion after each presentation and also at the end of all the presentations. I would request all of you to participate in these discussions so that, on behalf of INSA, we can produce a coherent document presenting our position in respect of our energy strategy.

OVERALL ELECTRICAL ENERGY SCENARIO AND HYDEL/MINI HYDEL ENERGY SYSTEMS

J.K. Bhasin
Chairman, CEA

PART—I
Overall Electrical Energy Scene

General

The availability of reliable and economic form of energy is a prerequisite for economic and social development as is clearly demonstrated by the close relationship between energy consumption and economic growth in industrialised countries and between the persistent energy deficiencies and low standard of living in many developing countries. Indian economy is primarily based on agriculture, about 73 per cent of its population lives in rural areas. Thus, the emphasis on the rural development, immediately after the attainment of independence, was imperative for the real advancement of the nation which required energy for irrigation, fertilizers etc. The fact that the rural energy consumption which was insignificant just after independence now stands at about 25 per cent of the total consumption indicates the progress made in this direction. The planners also thought, in giving the nation a strong industiral base and to meet the energy needs, of recommending setting up of big multipurpose projects and large power houses by utilising the traditional sources of power i.e., water & fossil fuels. These projects helped in the setting up of large industries in the Public Sector and created an infrastructure for the development of industries besides creating irrigation facilities which helped usher in the green revolution to make the nation self-sufficient in its food requirements. The industrial development, however, remained confined around urban areas without creating jobs in the villages. The energy demand of rural people, which used to be met from traditional non-commercial sources, is now getting more and more dependent upon commercial energy, due to changed socio-economic reasons. The availability of traditional sources of energy viz. wood, animal waste and agricultural-residue is becoming more and more difficult for the rural population to procure due to the indiscreet cutting of jungles and greater pressure on land. The share of traditional fuels in total energy consumption has declined steadily from 74 percent in 1953-54 to 60 per cent in 1970-71 and to about 44 percent in 1987-88. With

the low availability of these non-commercial traditional fuels, the use of commercial fuels such as coal, lignite, petroleum products and natural gas is increasing, resulting in erosion in the already meagre earnings of rural folks. The cost of these commercial fuels also keeps increasing due to the fact that these are getting exhausted and are non-renewable sources of energy. The problems have been accentuated due to the recent gulf crisis and also due to the resource crunch.

During the period from 1953-54 to 1986-87 the annual compounded growth rate of coal, oil and electricity consumption in the country has been 3.3 per cent, 6.8 per cent and 9.7 per cent respectively. Electricity has been the most preferred form of commercial energy over the years and present anticipations are that it will continue to remain so in the years to come. The policies and approaches adopted in power development so far have been to let the power supply industry expand at an average rate of doubling almost every seven years. The installed power generating capacity in India has increased during the last four decades from 1700 MW to over 64,000 MW. More than 86 per cent of our villages have been electrified and about 86.2 lakh pump sets/tubewells have been energised. Though the installed generating capacity in the country has increased manyfold since independence, the demand for electricity has been out-stripping the supply. As a result, we are facing a situation of shortages. At the end of the 7th Plan, taking into consideration the various restrictions etc. we were left with energy and peaking shortages of 18.0 BU (7.3 per cent) and 8200 MW (17.2 per cent) respectively on all India basis.

The Energy Requirements and Power Supply Position

The working Group on Power for the 8th Plan agreed with the energy projection of 385 BU as given by the 13th Electric Power Survey (EPS) and the projected peak demand of the order of 70,000 MW (against 73,000 MW as projected by the 13th EPS) by the end of 8th Plan. Consequently, the capacity addition required was of the order of 45,000 MW. The corresponding energy and incremental capacity additions for the 9th Plan would be 594 BU 62000 MW respectively. However, keeping in view the various fiscal constraints and non-preparedness of power projects for the commissioning of the units during 8th Plan period, the Working Group on Power recommended a capacity addition programme of 38369 MW comprising 7434 MW of hydro, 30230 MW of thermal and 705 MW of nuclear capacities for the 8th Plan period and about 100,000 MW for the decade 1990-2000 AD. The outlay

required to achieve the target for the Eight Plan has been estimated at Rs. 1,27,000 crore. The expected outlay available for the 8th Plan would, however, be around Rs. 70,000 crores, thus reducing the capacity addition to about 27,000 MW. The situation that we now foresee is of an increasing gap between demand and supply mainly due to scarcity of funds.

By the end of the 8th Five Year Plan period, even if success is achieved in adding, the capacity as recommended by the Working Group, the power supply position in the country is likely to face shortages of peak power ranging from 16.3 per cent to 19.2 per cent on All India basis, though the energy shortage may be only nominal, ranging form 3.9 per cent to 0.8 per cent. There will, however, be wide variations in the regional power supply position. In the event of capacity additions getting scaled down to 27,000 MW, the power sector would be confronted with a peak power shortage of about 15,500 MW (22.0 per cent) and energy shortage of about 16.0 BU (4.1 per cent) during the last year of 8th Plan.

The supply options available with us comprise of conventional sources like hydro, thermal including gas and nuclear and non-conventional renewable sources of energy like solar, bio-gas, wind, tides, sea-waves, ocean thermal energy etc. The traditional sources of power cost about Rs. 3 to 4 crores per MW including its transmission and distribution; the non-traditional sources, however, are likely to cost much more. The high incidence of transmission and distribution losses and the low level of plant load factor in many states have aggravated the problems of power sector. It would, therefore, be necessary to look for various options which could help in bridging the gap between supply and demand. Certain short-term and long-term measures such as renovation and modernisation of thermal and hydro plants to improve their performance, accelerated project implementation, undertaking short gestation schemes such as gas turbines, improving quality and quantity of coal reaching thermal power stations, reduction in T & D losses, effective interconnected operation of power systems, acceleration of hydro power development, strengthening of T & D system and regional grids, beneficiation of coal, diversification of fuels and modes of transportation of coal have been taken or contemplated to be taken. Another most important and cost-effective option available for bridging the gap between demand and supply of energy is “Energy Conservation”. Highest priority is being given to this field by conducting energy audit of industries and by introduction of energy efficient equipment and technologies in industrial and agricultural sectors. With these measures, savings of energy of about 25 per cent in these sectors should be a reality.

To implement urgently the energy conservation methods so as to save nearly 5,000 MW of future generation capacity, during the 8th Plan period, the Government has earmarked Rs. 1000 crores for energy conservation methods. Greater public awareness is being created by the Energy Management Centre and other Organisations. Further, in view of the major problem of resource constraints, Private Sector participation in the Power development programme has been contemplated. In the context of the present oil crisis co-generation is also being considered to substantially meet the power demand of various sectors of economy.

Over and above giving first priority to the development of hydro power in the country, it would also be desirable to consider the development of nuclear sources of generation taking into account the long-term energy needs of the country to effectively utilise the indicative and inferred reserves of Uranium and Thorium of about 67,000 tonnes and 3,63,000 tonnes respectively. Supply option from nuclear power is also very costly. Our efforts, therefore, should be to develop techno-economic viability of the energy options from non-conventional renewable sources so that these may compare favourably with the conventional path. It may be noted that exploitaion of most of the non-conventional energy sources on commercial basis, excepting for tidal power, has not been fully established so far.

PART—II

HYDEL/MINI HYDEL PROJECTS ENERGY SYSTEMS

Early Development

The mini/micro hydel power concept is not new. In fact, we in India like other countries entered the electric arena through very small hydro power plants. These plants were relegated to the background when mega projects to meet huge energy requirements came into existence and during this period small hydro projects like Glenmorgan in Karnataka were uprooted for giving place to the bigger projects. This plant was taken away for installation at Liemakhong in Manipur.

As per the existing definition, the stations upto 100 kW capacity with maximum unit size of 100 kW constitute micro and those of capacity above 100 kW and upto 2000 kW with maximum unit size of 1000 kW constitute mini hydel stations. India's first hydro-electric power station was mini hydro station and was commissioned by Darjeeling Municipality on 10th November,

1897, at Sidrapong in West Bengal having an installed capacity of 130 kW. An old Government House was the first house to get electricity for light from this power station. The power station had two single phase generating units each of 65 kW (230 volts, 83.3 cycle). With the growth of demand, 135 kW sets were installed in 1905 and 1909. Subsequently, these sets were replaced and present installed capacity of Sidrapong Power Station is 3 x 200 kW. A small power plant with an installed capacity of 4,500 kW was commissioned at Sivasamudram in the then Mysore State in 1902. Harnessing of the hydro potential of canal falls in India was taken up as early as 1930s. Eight such hydro-electric schemes were constructed before Independence on Ganga Canal in Uttar Pradesh.

Hydel Power Potential

Nature has endowed India with high mountains and a large number of small and big rivers. The Himalayas spreading across a length of about 3200km, and width of 640km. abound in hydro-electric potential with falls ranging from a couple of metres to a couple of thousand meters. According to the recent studies carried out by the Central Electricity Authority, the total hydro power potential in major and medium schemes stands at 84,000 MW at 60 per cent load factor. This is equivalent to hydro energy potential of 600 billion units per annum (including secondary energy). A systematic assessment of hydro potential in small hydro electricity (H.E.) schemes is currently being carried out by the Central Electricity Authority. A rough estimate of this potential places the figure at about 5,000 MW.

Possibility of small hydro schemes in the close proximity to the grid occurs largely at dams already constructed for irrigation and other purposes and at the falls available along with the irrigation canals. These schemes due to linkage with releases are seasonal and there may be periods when there are no releases at all. The power generation in such schemes is confined to a maximum of about 8 to 9 months in a year. In case of small hydro development on the canal falls, the power generation would have to follow the varying pattern of irrigation releases. In planning such schemes, emphasis may be on exploitation of maximum energy potential consistent with economy. Small hydro schemes on existing irrigation dams or on canal drops are expected to be free from land acquisition problems and environment and forest aspects. The small gestation period and simplicity of project layouts are added advantages.

In remote and hilly areas, the type of small hydro schemes are normally of run-off-river development type with or without diurnal pondage. From

the consideration of economy, it would be advantageous to have as high head as possible with given topography. All schemes in the hilly areas are not perennial. These schemes also have wide variation of discharges. The power generation in the lean period is relatively small in many cases.

Status of Development of Small Hydro Electric Schemes

The first long term power planning study carried out in C.E.A. during 1981 emphasised for a desirable mix in favour of hydro projects of at least 40 per cent by the end of 8th Plan period. However, the revised studies carried out in 1987 favoured for hydro generation of at least 30 per cent by the end of the 8th Plan due to changed system conditions. As against these recommended levels we may end up with less than 25 per cent share of hydro capacity in the all India generating capacity by the end of 8th Plan. This trend of lowering the share of hydro power in the various power systems of the country results in suboptimal utilisation of existing power plant capacity as the hydro power provides the much needed peaking power. In the absence of adequate hydro power plant capacity in the system, the peaking power is also provided by the thermal power plants resulting in their backing down in off peak hours. It would, therefore, be desirable that pace of hydro-power development is accelerated in future by making efforts in various fronts.

Most of the small hydro-electric schemes developed after Independence, are located in the Himalayas. These areas are thinly populated. Most of these schemes are located in the hilly regions of J & K, Himachal Pradesh, UP, Sikkim and Arunachal Paradesh. As on 31.3.1990, 126 small hydro-electric schemes with an aggregate capacity of about 223 MW were under operation in various parts of the country. A total of 100 small hydro schemes with a total installed capacity of about 248 MW were under construction.

Need for the Development of Small Hydro Power

In the wake of the energy crisis amidst which we find ourselves today, the development of small hydro stations by harnessing hilly streams and canal drops which was considered uneconomic earlier, has created renewed interest amongst the planners all over the world. Small hydro is an ideal source of energy supply to remote and isolated hilly areas. Small hydro units can play an important role in rural electrification. There are thousands of villages in the hilly areas where the transmission lines are not likely to reach in next 15 to 20 years. Harnessing small streams for power can usher

in an era of fast economic development in these areas. In the plains, small hydro development plays an important supplementary role in meeting the energy demands through the exploitation of available canal heads. Development of small hydro has little or no impact on environment and does not involve significant deforestation.

Strategy for the Development of Small Hydro Schemes

Considering the advantages of small hydro, Government of India has accorded high priority to the development of these schemes. One of the major factors which has come in the way of speedy development, is the high cost of construction of these schemes. The planning, design, construction and operation strategies for mini/micro/small H.E. schemes should be different from those for medium/major hydro schemes. It is necessary to reduce the cost of civil and electrical/mechanical works. The use of pre-fabricated structural components should be encouraged. Efforts should be made to use locally available materials to the maximum extent in the construction of civil structures. The following aspects should be considered to reduce the cost of electrical/mechanical equipment :-

- Standardising of project features, design, rating of generating units and other equipment;
- Use of electronic load controller for small capacity generating sets to obviate the need of governor and voltage regulator;
- Use of shop assembled package units;
- Use of induction generator in place of synchronous generator;
- Use of pump as turbine; and
- Use of turbines directly as prime movers for providing mechanical power.

To promote small hydro development in the country, Central Electricity Authority has brought out a publication *"Guidelines for Development of Small Hydro Electric Schemes"* which deal with the investigations, project formulation, design of civil structures and selection of electrical and mechanical equipments. To standardise all the major civil structures that are required, the Central Board of Irrigation and Power has brought out a publication *"Small Hydro Stations—Standardisation."*

The tendency to go for imported units for micro/mini/small H.E. schemes on the plea of reliability and economy is misplaced. There should be emphasis

to procure generating units from indigenous manufacturers in all cases where indigenous capacity is available.

Constraints

The main constraint in the development of small hydro power is the lack of funds. The State Governments are finding it difficult to provide adequate funds even for the ongoing schemes and there is a general lack of enthusiasm to take up new schemes in the remote areas because of the problems of inaccessibility, etc.

While pursuing the development of small hydro, side by side the performance of micro/mini/small schemes commissioned during recent past should be evaluated. It is understood the micro/mini/small hydro schemes in hilly regions are experiencing many problems, such as :

- The repair in case of breakdown of water conductor system and the power house take considerable time due to difficult road communication and frequent disturbance on account of land slides.
- Heavy siltation in the water conductor system during monsoon period causes lot of erosion in the plant and sometimes leads to its closure.
- Living conditions are difficult and suitable trained and technical personnel are not willing to be posted to such areas.
- Operation problems of the generating equipments are too many; and
- Spare parts are not available readily.

Conclusions

To sustain the tempo of development of small schemes, serious efforts need to be put in to find solution for the above problems by adopting corrective measures in planning, design and manufacture of equipment for these schemes. There is an urgent need to enforce quality assurance during manufacture of equipments.

The importance of small hydro cannot be overlooked. However, small hydro should not be taken up without proper costing and economic justification. Small hydro has to compete with other alternative sources of energy keeping in view the limited financial resources. A strategy has to be based on sound techno-economic consideration and financial judgement. It is essential that small hydro schemes are economically viable consistent with acceptable levels

of technical reliability. The cost-analysis of some of the small hydro projects has indicated tremendous rise. The per MW cost has gone up to as much as 3 to 4 crores. This trend has to be stopped.

Discussion

Q. Efficiency claimed by western countries is much higher than what we are able to achieve. Please comment.

A. In the beginning when we were new and were planning our own plants, we were using a figure called 'Plant Load Factor' or PLF. That was 42% or so. Today it has come upto 56% after doing a lot of renovation and improvement. But it has again shown downward trend and has come to 52 per cent of the capacity. It is not because the plant or production is inefficient. It is because of the consumption pattern. Supposing I have 100 MW at peak hours but when peak load goes away the demand may be only 40-50 MW. So I cannot produce though the plant is available. Now, when we have reached quite an efficient stage, plant load factor is not the indicator, it is the plant availability. Plant is available 80-90% of the time but I could not utilise because we have no load. It is unlike sugar and cement that when demand is not there we can still produce at the factory and store it. But electricity cannot be stored. Supposing today in the morning we had a frequency as high as 51.2, it becomes a bad operation because it is damaging the turbine. But because of certain reasons, people tend to generate more so that we can get a high PLF. But, we have to get rid of this concept of high PLF. Somehow this figure has become so popular in the country. Now we have to depopularise PLF. PLF is not the only indicator, it will be ultimately decided by the cost. Gujarat has done very well. They did not insist on their PLF. They purchased power from NTPC and showed that they have gained about Rs. 5 to 6 crores per year instead of having an award of high PLF.

Q. Did you say anything about the percentage loss during transmission? Second, is the data which you have presented the installed capacity or is it the actual production?

A. No, it is the installed capacity with the utilities.

Q. What about losses in transmission?

A. Supposing we generate 10 MW power under our present circumstances. Of this not more than 7.5 MW must be reaching the consumer ends.

That is our loss from station busbar to cunsumer end. Where these losses are taking place, transmission, distribution, the consumer ends themselves—we have not been able to know because in this country lot of that is going in theft. You will have noticed people throwing some hooks on the line and tapping it. Lot of energy under the '*Kutir Jyoti*' or '*Jaldhara*' schemes is unmetered energy. So, the position today is that we are not able to detect where the losses are, in what sector, so that we could take remedial measures. Because, it is no use just all the time groping in the dark. Our transmission losses are high and we go on spending on transmission. We have to first analyse and analysis can be done only when we change our tariff structure and go for proper metering of each and every thing. You may give free electricity, let someone else pay and not the producer. Then only things can come to a certain level.

Q. These days we are hearing a lot about privatisation so far as power generation is concerned. Would you throw some light as to what will happen in terms of power utility? Let us say under different scenarios of rural income but 10%, 5%, 3% of power being generated by private parties.

A. About the private sector as far as our electricity legislation was concerned, it never debarred the private participation. It only restricted certain profitability that too not beyond a certain limit. It was the industrial policy resolution of 1956 which says "generation, transmission and distribution of power, just like some other core sectores, would be under the public sector." Today when we find ourselves confronted with the financial crunch, we are inviting private sector to participate. What return are we giving them? - 12% as per electricity act. The return is being increased and certain stipulations which are not there in the legislation but in the privatisation bill these are being made, i.e. how much money the promoter himself has to bring in. That is why you must be reading in the newspapers that even authorities of states are trying to give their hydel power projects to private sector. Some of these may be personal views but as far as the Government is concerned, they are not against private sector participation.

COAL BASED ENERGY SYSTEMS

B.V. Chitnis
Vice-Chairman, Tata Consulting Engineers

General

The energy programming in India must necessarily be based on coal as the major fuel source because of its abundance, Fig.1. The estimated reserves of coal in India are 170 billion tonnes. This is 4% of the world reserves. Of this amount only about 60 billion tonnes or 0.8% are extractable. In 1989-90, 184 million tonnes of coal was mined through open cast (63%) and underground (37%) mines. The annual production projected for 1994-95 is 271 million tonnes and for the year 1999-2000 it is about 350 million tonnes. Of the total coal produced, about 62% is used for power generation, 12% for steel production and cement, fertilizers, etc. consume about 26%.

- **Reserves - Billion tonnes (% of world reserves)** **170 (4%)**
- **Extractable** **60 (0.8%)**

	)89-90	*1994-95 (Projected)*	*1999-2000 (Projected)*
● **Annual production (million tonnes)**	**184**	**271**	**350**
Open cast	**63%**	**67%**	
Under ground	**37%**	**33%**	

- **Coal fields**
  Raniganj, Jharia, Bokaro,
  Singarauli, Talcher,
  Pench, Kanhan, Chanda, Wardha,
  Singareni,
  Neyvelli, Cutch, (for lignite)
- **Usage**
  - **Power 62% Steel 12%, Cement, Fertilizer etc. 26%**
- **Characteristics**

	overall range	*to power stations*	*other countries*
● **Gross cal value (kcal/kg)**	**3000-6000**	**3000-4500**	**5730-7600**
● **Ash content %**	**15%-50%**	**35%-50%**	**8%-16%**

Fig. 1 Coal Resources of India

The quality of Indian coal is not very good. Its gross calorific value lies in the range of 3000-6000 kilo calories per kilogram of coal as against the value of 5730-7600kcal/kg obtained in other countries. The ash content of our coal is also high being 15-50% as against 8-16% found in the coal available in other countries. The coal supplied to the power stations is of poor quality. Its calorific value is 3000-4000 kcal/kg and ash content is 35-50%. Our coal fields are located in Raniganj, Dharia, Bokaro, Singarauli, Talcher, Pench, Kanhan, Chanda, Wardha, Singareni, Neyvelli, Cutch (lignite), Fig. 1.

Power Generation

The total installed capacity of power generation as of March 31, 1990 was 62363 MW, Fig.2 of this, 40570 MW or 65% is coal based inclusive of oil and gas fired thermal units, 18088 MW or 29% is hydel, 2090 MW or 3.4% is gas based (gas turbine units) and 1465 MW or 2% is nuclear, Fig.2 From this it is clear that our hydro/thermal ratio is very poor and coal is the most substantial source of energy for us. But coal is difficult to produce, transport and handle at the receiving end. It is a fuel difficult to burn and safely dispose off the effluent products without affecting the environment.

Problems in Production and Transportation of Coal

Coal mining in India is insufficiently mechanized and is therefore too man-power-intensive. The productivity is low and activity very hazardous. It is also very difficult to manage the quality of the product and there is serious impact on the environment.

Transportation-wise railways are unable to provide adequate facilities or devise technological and innovative solutions to the rising demand for coal transportation. Railways, coal producers and power plant managers have never got together to find solution to what is required. The second major problem is that coal is sold in terms of tonnage. We would like it to be sold for its energy content in terms of Btu. There is very poor coordination among coal producers, transporters and consumers for the optimum use of resources and equipment. Therefore, there are problems with producers, the transporters, and even the users who are all Government agencies and all commercial transactions are done with Government sanction. Market forces do not or are not allowed to operate so that the ultimate consumer gets timely deliveries of consistent quality coal at the lowest possible delivered

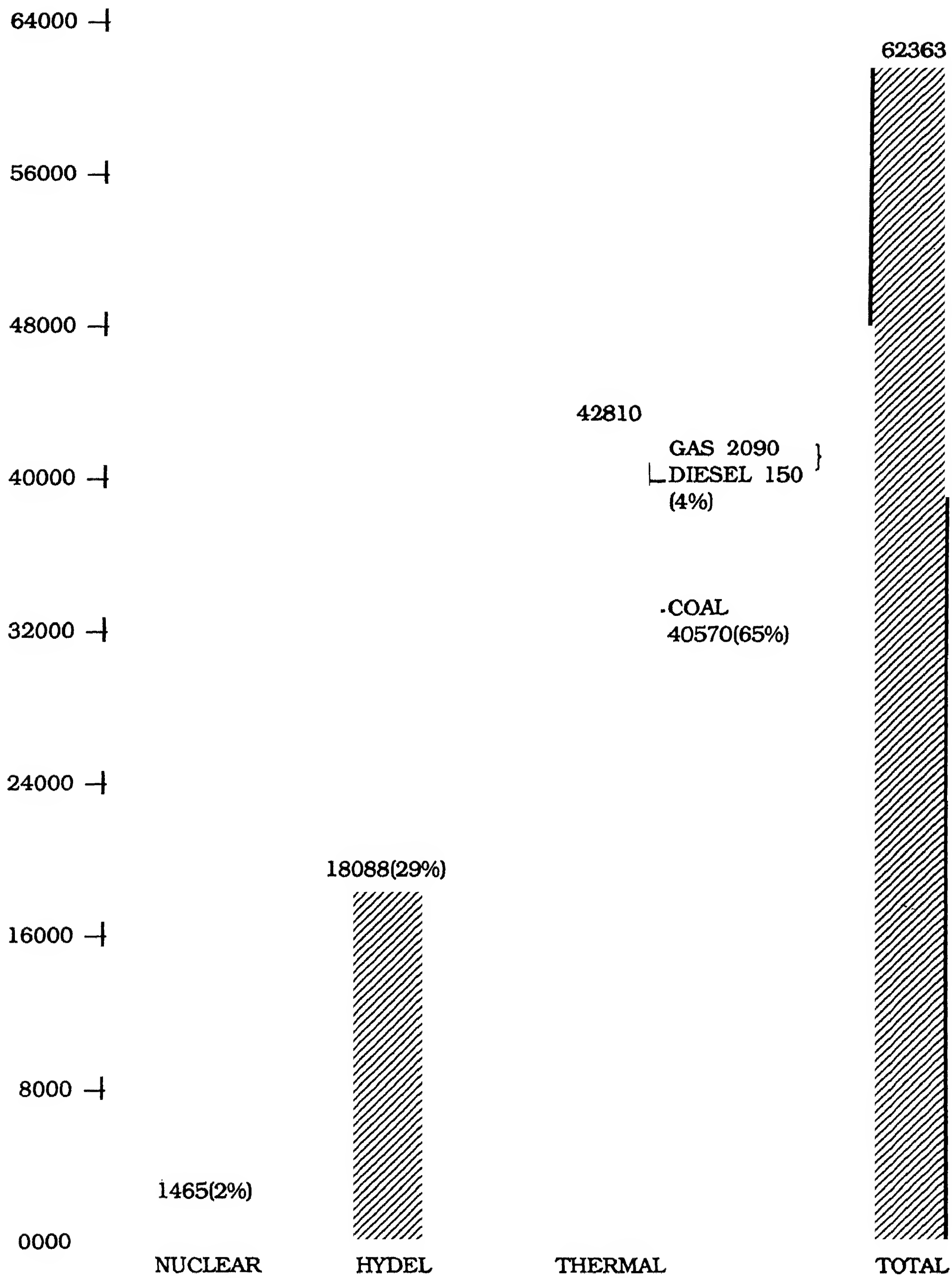


Fig. 2 Present Installed Capacity of Power Generation (As of March 31, 1990)

1 *SOURCE* A) FOR NUCLEAR, HYDEL, COAL AND GAS BASED UNITS *VIDYUT BHARATI* (JULY-SEPT 1990)
(B) FOR DIESEL UNITS — TERI DIRECTORY (1989)

2 COAL (40570 MW) ALSO INCLUDES OIL AND GAS FIRED THERMAL UNITS

3 GAS (2090 MW) REFERS TO GAS TURBINE UNITS

energy cost. Individual actor should be able to take his commercial decision appropriate to the demand situation as he sees it at that point of time. Secondly, producers and transporters have not been able to deploy sufficient capital and manpower resources for technology upgradation. Nor has it been possible for institutions to find innovative solutions through research and developmental activities or otherwise. In the western countries they could do so in every sphere of mining, transportation and usage and have thus kept pace with the times. For us the situation is very serious.

The solutions being investigated are (1) slurry transportation, (2) Underground coal gasification, (3) coal beneficiation. There is a Demo project to transport 0.8 million tonnes of slurry per annum over 33km from New Mari to Chandrapur. The slurry consists of 50 : 50 coal : water mixture. There are two projects with an estimated investment of Rs. 15 crore for underground coal gasification. One project is by Coal India of depths upto 800m and the other by ONGC for depths greater than 800m. Third solution which has been talked about for quite a long time is coal beneficiation. Commercial trials at Nandan Washery for Satpura thermal power station (tps) have shown the advantages of coal beneficiation. Ash reduced to 32%, indicated coal consumption reduced by 25% and PLF improved from 82% to 97%. There are techno-economic studies that have been done for various locations; Kayamkulam tps in Kerala linked to Talcher, Yamunanagar in Haryana linked to North Karanpura, Dadri tps, Tuticorin tps, South Madura tps. All of these studies have indicated that there are advantages to be derived from coal beneficiation.

Our organization has carried out some studies on the economics of minemouth coal beneficiation. The major advantages of coal beneficiation lie in (a) uniform and predictable quality as to ash content, (b) calorific value, (c) size and fines. The reduction of ash content to 35% is recommended as further reduction is not cost-effective. Reduction in ash content reduces transportation loads and costs. With high ash content and transportation beyond 500 miles, the transportation cost is higher than the cost of coal itself. Reduction of ash also causes a reduction in coal handling, ash handling, milling plant and the capacity of the electrostatic precipitator (ESP). It also gives you lower auxiliary consumption. It obviously gives you a reduction in capital and maintenance costs and as mentioned earlier plant availability improved greatly by as much as 750hr/yr.

A small study was done for a particular situation of a 2 x 210 MW station, 500 km from minemouth to find out the costs and benefits of coal beneficiation.

– Beneficiation Plant Cost @ Rs. 8 lakhs/TPH	Rs. 4000 lakh
– Annual costs	
• Extra for beneficiated coal	Rs. 405 lakh
– Annual benefits	
• Improved availability 500hr/yr	Rs. 2100 lakh
• Reduced auxiliary consumption	Rs. 56 lakh
• Reduced maintenance	Rs. 45 lakh
Annual savings	Rs. 1796 lakh

Payback period

Distance of tps from mine mounth (km)	Pay back period
100	Viable
200	4 yrs
400	3 yrs
500	2 yrs

Thus, we see that depending on the distance the payback period is 2-4 years. The question then is "If coal beneficiation is a cost-effective solution then why are we not in a position to adopt it?" The problem is that the capital investment is to be made by Coal India but the benefits are to the electricity boards and as far as railways are concerned they are not interested in transporting coal in any case. So, the three factors in this whole business cannot come together to find a common solution. I think there is no commercial mechanism by which the benefits of a cost-effective solution, if there is one, will be shared by the three involved parties. Another major problem is that the improvement in availability is intangible and often a debatable question and one can never prove the improvement in availability. Obviously when the improvement is an intangible quantity, you tend to believe that the cost-effective exercise is academic and one cannot take bad commercial decision.

Problems of Coal Handling and Ash Disposal

Power stations have to handle coal upto sizes of 600mm, which is greatly oversized. I think that there is no power station or coal handling system

that can be designed to handle 600mm size at one end and fine dust at the other. The second problem is that of the extraneous matter that you get along with coal — shale, stones, metallic pieces, in fact you get wagon parts along with it. Further, the metallic parts are not only iron, iron can at least be removed, there are all kinds of other metallic parts which have to be almost picked by hand. Coal fines are upto 40% in the bulk supply and therefore the handling requirement is that of large lumps and fine dust which cannot be done. The second thing is that we have our open cast mine over-burdened and there is a clay overburden. This clay over coal causes lots of problems in monsoon. Clay mixes with ash and becomes sticky which is very difficult to handle.

Then, there are the problems of coal quantity and quality measurement. As you know coal is sold on the basis of the receipt that the railways give to the power station at the other end. That is sometimes measured, sometimes not even measured because you have too many wagons with 65 tonnes of coal and railways do not take any responsibility for pilferage on the way. The power stations have to accept whatever is being delivered to them. Secondly, there has never been an agreement between the supplier i.e., Coal India and the Electricity Boards to say "can we measure what is the quality of coal that is being delivered because there are about eight A to G classifications of coal and the prices for different qualities are different." Obviously, the power stations get only one quality which is the worst quality. There is no relationship between the calorific value that is received and the calorific value that is supposed to be contracted for. Thirdly, there is the problem of inventory management. Situations arise when the power stations are left with very little stock and are almost on the verge of shutdown and the railways say that you never ordered well in time and we have the problem of wagons. So this has never been sorted out that who should store coal and where? How flexible the quotation should be, etc. are matters never resolved satisfactorily.

Then, there are technical problems such as wear in handling ash, inadequate land for ash disposal and environmental hazards. This seems to be becoming a very serious issue because of insufficient marketability of ash utilization products. There are only two ways by which ash can be converted into any kind of a commerical product. One is to convert it into bricks. This has never been a commerically viable proposition. The second is to convert ash for use as an aggregate. This is a very new technology as I understand and I think Tata's invested some money and are at present negotiating

with some technology supplier. Again the problem of tranportation will arise. Obviously you can create a product which must be saleable at the power station or at least nearby. Then there is the lack of agreement among the coal producers and consumers as to the nationally most optimum solution for ash disposal. Should it be done at the minemouth through coal beneficiation, or at power station as flyash as is being done now mostly or should it be transported back in empty wagons to the underground mines or for that matter even the opencast mines?

Problems of Coal Burning

The major problems of coal burning are obviously that of wear, rejects, flame stability, slagging, dust precipitation, and NOX emission. Obviously, some of them have got technological solutions. Wear can be taken care of by choosing the right material. 'Rejects' is a peculiar problem of one type of milling plant in its combustion. Other types of plants do not have the problem of 'rejects'. Ramond Bowl (CE), Babcock & Wilcox (B & W) milling plants do not have the problem of 'rejects'. The third type of plant now being recommended by Bharat Heavy Electricals is a Tube (Stein) mill and which I think has a core to handle the kind of coal that all the power stations in India receive. Lignite obviously requires a different kind of milling plant altogether. Different plants have different periods of working after which they require maintenance, CE 3000-4000 hrs, B & W 7000-8000 hrs., Stein more than 10,000 hrs. Then for 'reject' handling there are various technological solutions viz. manual, belt conveying, sluicing and pressurized pneumatic (dense phase).

The furnace obviously should be designed to burn the kind of coal the power stations get, provided of course, you are sure that quality will remain consistent. The parameters of furnace design have undergone numerous changes and at present they represent the best parameters to handle Indian coal, Fig.3. Obviously one has to provide sufficient redundancy knowing that coal is a difficult fuel to burn to ensure that its availability is not affected.

Coal is transported through several modes. Road transport is used only in a limited way and in emergencies. Inland Waterways on barges, have limited applicability. Ropeway and belt conveyors are used within a distance of 10km for 50 tonnes per hour or higher capacity. Railways and rail-cum-sea are the most common mode of transportation over long distances. And coastal locations are trying to get coal increasingly by ship.

- **Major Problems**
  - **Wear**
  - **Rejects**
  - **Flame Stability**
  - **Slagging**
  - **Dust Precipitation**
  - **NO_x Emission**

Various Solutions

- **Choice of Milling Plant**
  - **Raymond bowl, (CE) — med speed for not too Abrasive Coals**
  - **Ball & Race (B & W) — med speed**
  - **Tube (stein) — Low speed for High Abrasive Coals**
  - **Hammer & Beater Wheel for Lignite-High Speed-for Low Abrasive Soft Coals**

Life Expectancies of Wear Parts

CE	—	3000-4000 hrs
B & W	—	7000-8000 hrs
Stein	—	>10,000 hrs, concides with annual BLR recertification

Reject Handling
- **Manual**
- **Belt Conveying**
- **Sluicing**
- **Dense Phase — Pressurized Pneumatic**

Furnace Design
- **Vol Heat Release Rate ≅ 100,000 kcal, cu.m/hr,**
- **Plan Area Heat Release Rate ≅ 4.75 x 10^6 kcal/sq.m/hr,**
- **Burner Zone Heat Release Rate ≅ 1.55 x 10^6 kcal./sq.m/hr,**
- **Fegt 75 °C below Ash Initial Deformation,**
- **Flue Gas Velocity reduced from 12 to 10 m/s,**
- **Sacrificial Baffles & Shields,**
- **Low NO_x Burners,**
- **Flame Stabilization & Oil Consumption Control,**
  - **Split Nozzle Burners,**
  - **Direct Ignition of Pulverized Coal,**
  - **LCV Gas Flame Stabilizers.**

Redundancy
- **Two standby mills on guarantee coal**
- **One standby mill on worst coal**
- **Mill loading < 85%**
- **Redundant coal burner row**

Fig. 3 Problems of Coal Burning

Problems of Coal Burning—Effluent Management

The problems of ash arise after the fact that ash has to come out of the sifted openings and the equipment that has to handle ash are subjected to all kinds of failures. Ash is a very fine material and it is very difficult to handle. It is hygroscopic and it requires lot of water for removing and

disposal. Fig. 4 lists other effluents, relevant environment protection standards and necessary equipment.

While coal is difficult to handle, long term solution lies not in avoiding, but meeting all the technological challenges in plant design, O & M and innovative use of coal as energy source. Solutions fall in four categories viz.

- **Standards**
  - **Particulate** — **150 mg/nm³ IS**; **17 mg/nm³ EPA**; **& 20% Opacity**
  - **Sulphur** — **By Chimney Height (CEA STD.)**

Plant Capacity	Chimney Height
< 200 mw	$H = 14 (Q)^{0.3}$ Q= total SO_2 Emission
200-500 mw	220 M
> 500 mw	275 M
0.6 lbs/mill btu or 70% removal	EPA

Fgd not statutorily required in India

NO_x — **NO is, no statutory requirement**; **Specified to EPA standard of 0.6 lb/mill BTU**

Equipment for Effluent Control

- **Particulate**
  - **Mech Dust Collectors**
    Max eff 80%
    Inadequate to meet is
  - **Electrostatic Precipitators**
    eff upto 99.7%
    meets is
    Costlier to bhf by 20-30%
  - **Bag House Filter (bhf)**
    eff upto 99.99%
    High Running Costs
    - **High Press Drop**
      200 mm *vs* 25 mm for ESP
    - **Bag Replacement**
  - **Flue Gas Desulphurisation**
    - **Only Installation at Trombay TPS**
  - **Flyash Disposal**
    Slucing
    Hydro Pneumatic
    Gravity
    Feeder Ejector
    Dense Phase
    Ejector Vacuum
    Slurry Pumps
    Vacuum Dry Flyash
    Dry Flyash-Vacuum-Press

Fig. 4 Coal Burning Effluent Management

(i) adopting fluidised bed combustion (FBC) technology, (ii) coal gasification, (iii) efficiency management, (iv) improved materials. The FBC is of two types (a) atmospheric FBC which again is of two kinds; bubbling bed and circulating bed and (b) pressurised fluid bed combustion. The advantages of FBC are that it absorbs upto 90% of SO_2, it avoids expensive flue gas desulphurisation (FGD) plant, high ash containing coal can be burnt and NO_x emission is also low due to low furnace temperature. We have no statutory requirement in respect of SO_2, therefore, this kind of solution becomes outmoded and people do not tend to adopt this. The second aspect is that FBC boilers are of limited capacity and in our context of 500 MW plants become irrelevant at least at present. As far as integrated gasification cycles are concerned, (Fig.5) there are four types with increasing sophistication. (1) Integrated Gasification Combined Cycle (IGCC) which have been in use for some time are DOW, USA 160 MW, Shell, Holland, 250 MW; UHDE, Germany 300 MW; TEXACO, USA 100 MW. (2) The integral gasification with humid air turbine (IGHT) takes care of the fact that instead of having a water and steam cycle, low level energy steam is used to humidify the compressed air that goes into the gas turbine to increase the mass flow and gives almost the same kind of efficiency. Then there are two laboratory solutions. (3) Integrated gasification with molten carbonate fuel cell (IGMCFC) which is expected to give an efficiency of 60%. As far as more efficient steam cycles are concerned, if the number of heaters is increased there is 1 $^1/_2$% increase

Types

● **Integrated Gasification Combined Cycle (IGCC)**	
Dow, USA 160 MW	
Shell, Holland 250 MW	**8200 bn/kwh**
NHDE, Germany 300 MW	**42% η**
Texaco, USA 100 MW	
Integrated Gasification — Humid Air Turbine (IGHAT)	
No Bottoming Steam Turbine,	**8100 bn/kwh**
Instead Turbine Exhaust produces steam to	**42% η**
humidify compressed air — increases mass flow	
Integrated Gasification — Molten Carbonate Fuel Cell (IGMCFC)	
● **Coal gas produces electricity in fuel cell**	
● **Heat in gas exhaust to bottoming cycle**	**7500 bn/kwh**
● **Demo Plant — 100 kw eff 45%**	**45% η**
Advanced Gasification — Molten Carbonate Fuel Cell (AGMCFC)	
● **Recycling exhaust gas to gasifier**	**Recycling H_2 to**
● **EFF 60%**	**the gasifier**

Fig. 5 Integrated Gasification Cycles

in efficiency. If you go to a higher throttle steam temperature, you can reach almost 4% increase in efficiency. I believe that this perhaps is a solution closer to our situations.

Conclusions

Coal based energy is unavoidable. There is need to upgrade skills in operation and maintenance of coal based plants. Innovative but practical solutions for mitigating coal burning problems of wear, SO_2, NO_X, low efficiency are all available. The commercial environment must be such that optimum solutions must be saleable to meet the unavoidable energy demand. And rising energy demand will require adoption of sophisticated technological solutions.

DISCUSSION

Q. I think Mr. Chitnis, what you said on effluent management is something more serious. May be in our recommendation we can mention that there are no Indian standards for sulphur dioxide and some other things.

A. In terms of the Environmental Protection Agency (EPA), there are two perceptions, one is chimney. As far as we are concerned, chimney is an appropriate solution because it reduces the ground level concentration. You know it distributes the same amount of sulphur dioxide over wider area. Therefore, the concentration is low. The concern in the western countries is that because of the total volume of energy that they produce, they have the problem of acid rains and they have problem of their forest being affected. So the EPA standard goes by the total amount of sulphur that is being emitted. In fact if you take the latest EPA standard, you will find that they have decided that over a period of time sulphur dioxide emission will be reduced in quantum and has decided the amount each producer can release. They can trade those. That means if you take care of sulphur more than what your quota is you can sell the amount you have saved to somebody else.

Q. Why is sulphur not a problem in India?

A. One reason why SO_2 pollution is not a serious problem in India is that our coals are low sulphur coals. The average content of sulphur in Indian coals, with the exception of south coals and some coals in Chanda area is only around 0.4 to 0.5%, whereas the coals they get in the United

States and Canada are in the range of 2 to 3%. So with the low sulphur content and with the low density of electricity generation in India, the perception is that sulphur is not a major problem and in fact acid rains have not been noticed in India at all.

Our Department of Environment have now made a standard for sulphur dioxide, and they insist on its being implemented. So, all the future projects for which we are giving technoeconomic sanction, we are giving with a condition that space will be left for de-sulphurising gas plant. The cost of desulphurising plant is about 25% of the cost of power station itself. So, we have to strike a balance between the two. As Dr. Chitnis has pointed out that firstly our percentage is quite less at the present and the density is also less. For the BSES plant in Dahanu it is provided that as and when required, this plant will be established there. This is the present position.

We must also remember that sulphur may be removed from air but then it finds itself in sludge. In western countries they have a big problem of how to handle sludge unless you convert sulphur dioxide into gypsum or some other product where sulphur is fixed.

Q. Will you please tell about the cost effectiveness of the fluidised bed?

A. Firstly, the fluidised bed boilers are not sufficiently large in size that we can use them. They have been used mostly in industrial plants and at the moment, I think, there must be about 10 to 15%, perhaps not even that much capacity. Secondly, the advantage of fluidised bed is again in sulphur entrapment in the bed and sulphur is not an immediate problem for us.

NUCLEAR ENERGY SYSTEMS

Anil Kakodkar
Director, Reactor Design & Development Group
Bhabha Atomic Research Centre

Background

Though nuclear energy is the youngest of the technologies for bulk electricity generation, fair amount of self-sufficiency has been achieved solely on domestic efforts. As of now, in addition to the two boiling water reactors supplied by General Electric, USA, we have two units of 210 MWe each operating at Rawat Bhata in Rajasthan, two units of 235 MWe each operating at Kalpakkam in Tamil Nadu and one unit of 235 MWe at Narora in U.P. All these units are of Pressurised Heavy Water Reactor (PHWR) type which forms the mainstay of current stage of our nuclear power programme. These units are built in the country with very small expenditure in foreign currency. Together, these seven units represent an installed generating capacity of around 1300 MWe. Seven more similar units are under construction now. Even so, the nuclear contribution would remain rather small as compared to the kind of total demand we are talking about today. In contrast, globally 319000 MWe capacity in 434 nuclear units represents 17% of total electricity generated and is comparable to the total hydroelectricity supplied the world over. And there are some countries who have in fact made inroads into the nuclear realm to as high a level as 70%.

Before discussing the Indian scene further, it would be worthwhile to find out "What exactly have been the benefits?" One benefit is that of reduced environmental pollutants (CO_2 and SO_2) burden added to the atmosphere. Take the case of a country like France where very large contribution to the total electricity produced comes from nuclear. There, the relative generation of CO_2 has been going down as nuclear energy production has been going up, Fig. 1. Relative CO_2 generation here means the contribution of CO_2 had the electricity not been produced by nuclear means but by thermal means alone. The same is true with regard to oxides of sulphur. It is an important pollutant particularly for the western countries (because of very high sulphur content in their coal) and they have brought it down to 10% of what it would have been had they not gone for nuclear power, Fig. 2. So, we take note of the fact that lot of benefits have been derived not only on purely commercial basis but also on the protection of the environment as a whole.

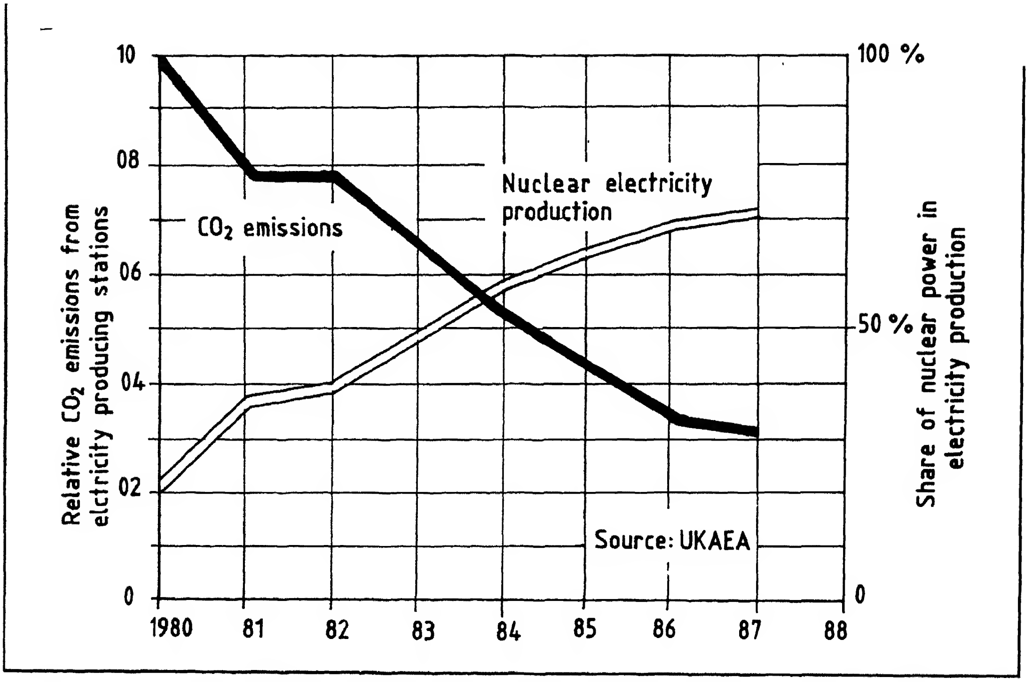


Fig. 1. Nuclear Energy Production and CO_2 Reduction in France

For us there is also the question of long term energy security specially in view of the recent Gulf crisis and its impact on our energy supplies. These are some of the points we keep at the back of our mind as we go along with the discussion in regard to the development of nuclear power in our country.

Energy Resources

In Table I, available resources of energy in our country are listed. This is just a different way of presenting the energy resources. I have put this in terms of tera-watt-year (TWY) which is roughly equivalent to a million tonnes of coal. If you put 450,000 MW as electricity requirement sometime in the next century, say year 2020-2030 or thereabout, the coal equivalent requirement for this would be roughly 1 TWY. That is the kind of energy that would be consumed. It is thus essential to mobilise our all available natural resources and in the short term exploit each one of them. But, the major contributions have to come from coal, hydro and nuclear and that of others rather small. Non-conventional energy sources have their important role in terms of decentralised energy supply. However, in the context of bulk central electricity generation, their contribution is expected to be marginal.

TABLE—I

Our Energy Resources

(in billion tons of coal equivalent or TW years)

OIL	0.6	
GAS	1.5	Requirement of Electricity Production in Early Next Century ~ 0.45 TWe
COAL	150	
URANIUM (ONCE THROUGH)	1.2	
URANIUM (RECYCLE IN BREEDERS)	100	
THORIUM	600	
HYDRO/YR	0.16	
BIOMASS/YR	0.048 *	
WIND/YR	0.004 **	
SOLAR	EXPENSIVE, DIURNAL & SEASONAL	

* can be realised if 20% of total waste land is utilised for energy plantation
** maximum capacity 20,000 mw with plant load factor of around 15-20%

Taking a long term view we therefore cannot afford to ignore the nuclear resource component that we have with us.

Large energy potential offered by nuclear resources is the primary motivation behind our efforts to develop nuclear power and secure our long term energy supply. This energy security deserves due importance in our planning. The recent events have shown the severe impact our economy would have to suffer even with marginal increase in the imported energy content.

Experience

Let us now look at a comparison of capacity factors: average of all thermal power plants (TPP) or coal units and average of all nuclear power plants (NPP), Fig. 3. This comparison is somewhat inappropriate. One cannot really compare the average capacity factors of 6 or 7 units with the average capacity factors of a large number of units. Any problem in any of the units when the total number of units is small can create a lot more impact on the capacity factor. You will notice from this comparison that we have been doing reasonably well. There is of course scope for considerable improvement. I am sure, as more units get added up we will be able to see better average capacity factors. We must note here that capacity factors achieved in many countries are quite high, to the tune of 75%-80% and even beyond. We should

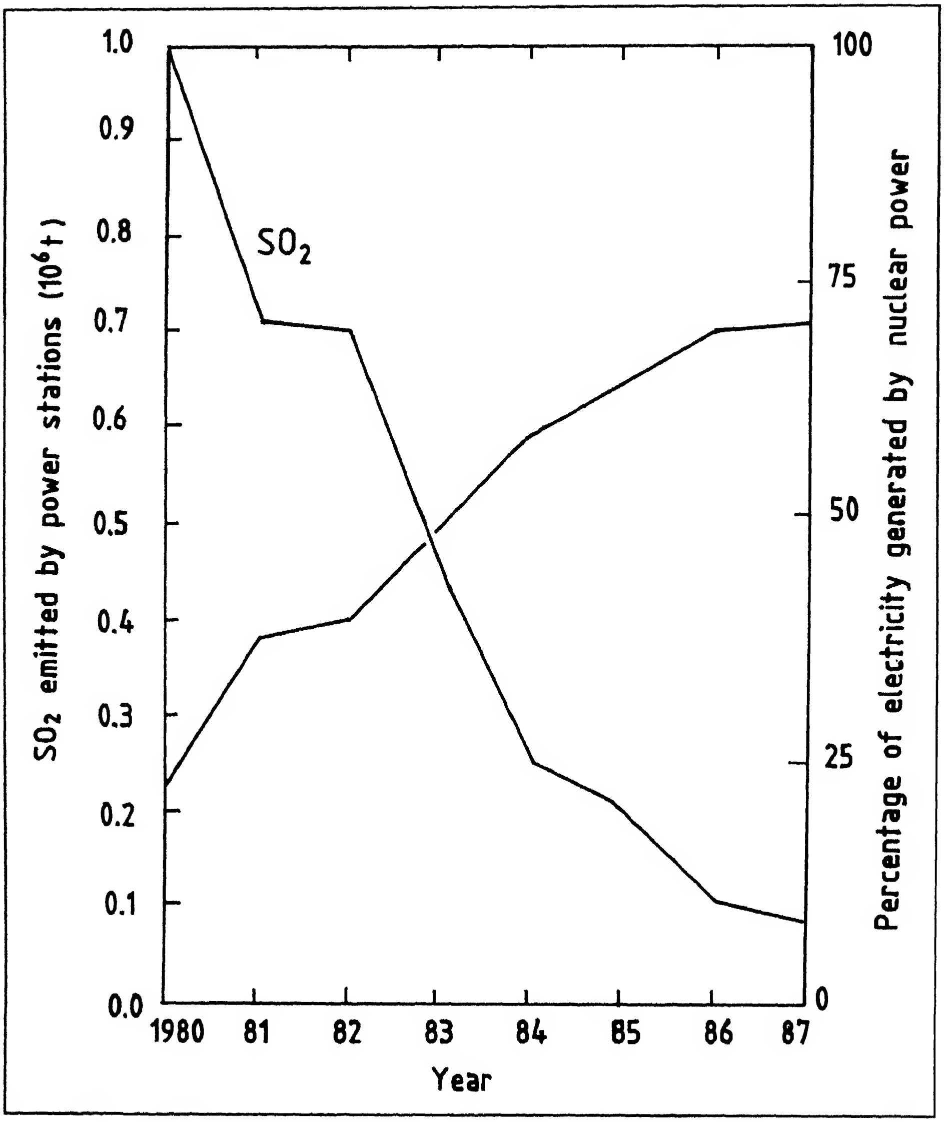
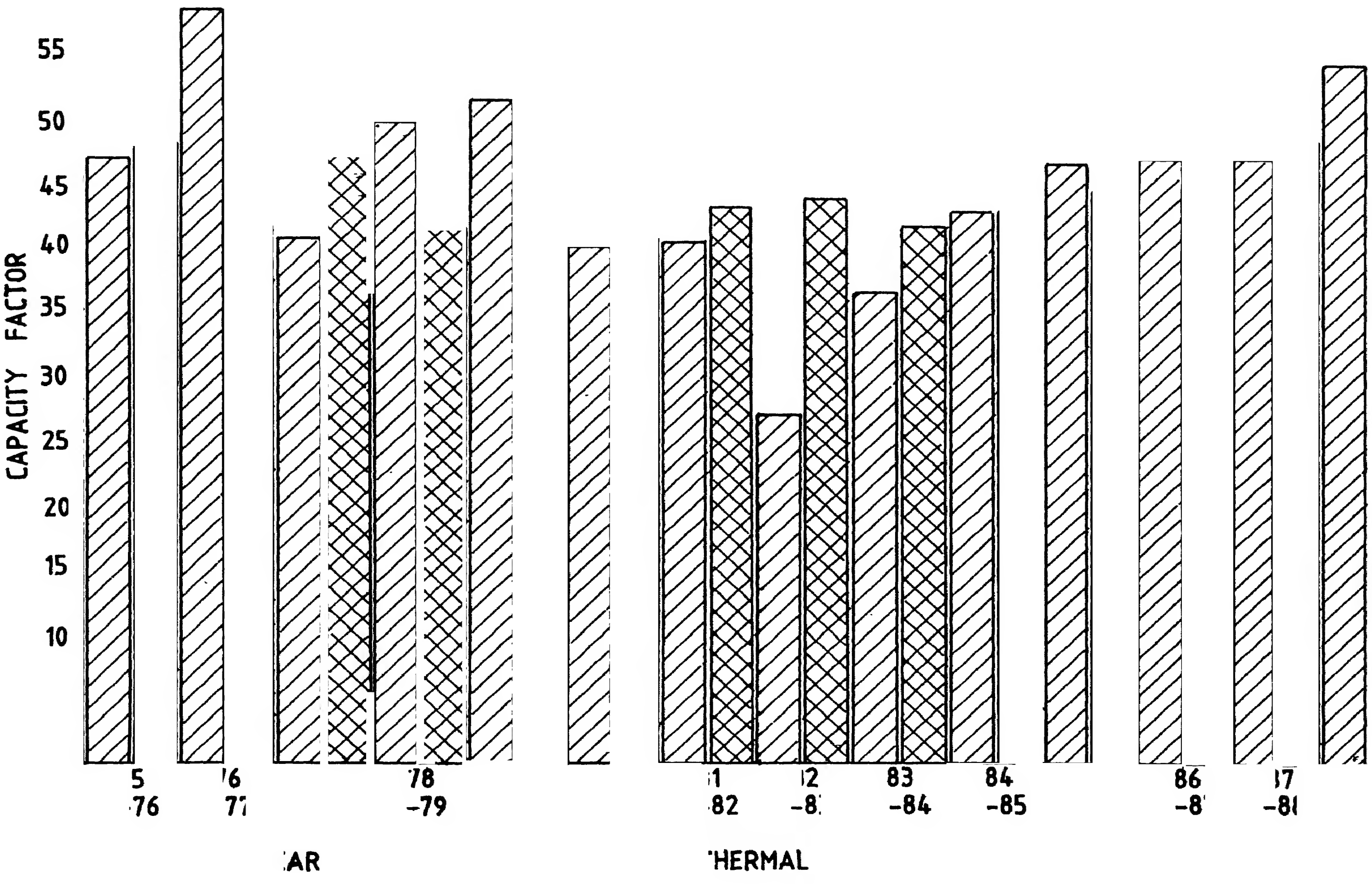


Fig. 2. Electricity Production and Pollution Reduction in France

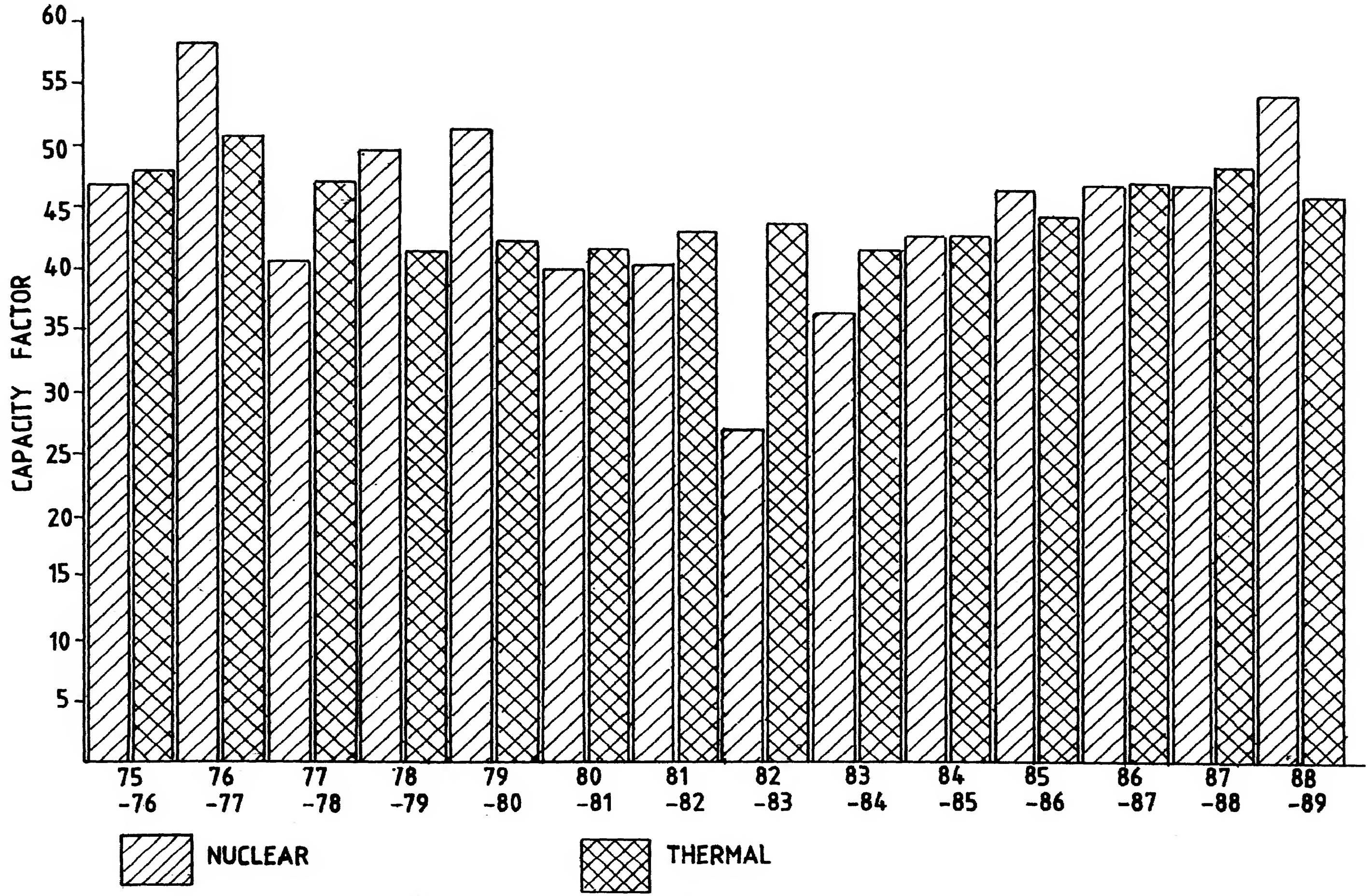
aim to achieve such targets. This will show up even better in the capacity factors which you achieve here and are seen in Western Countries. The latter are quite high, to the tune of 75%-80% and even beyond. Such capacity factors will not be difficult for us also to achieve when the total number of units that we are talking about become operating units.

Fig. 4 has been picked up from an International Atomic Energy Agency (IAEA) study where a comparison of energy cost between coal based electricity



Bhattacharya A. K. Elec. er erg; Envi ien

Fig. 3. Capacity Fac('or Nuc(and Stati(in India



Source : Bhattacharua A. K. Elec. energy & Environment. 1990

Fig. 3. Capacity Factors for Nuclear and Thermal Power Stations in India

and nuclear electricity has been made for various countries. It is not the intention to go into details here. But the point is that nuclear energy has been found to be commercially viable in a large number of countries. There may be, depending on the local situation, some variation here and there. But, if you are considering a scenario involving large inputs in terms of, I believe it is a supposition worth investigation particularly when we are planning for large electricity generation, it is clear that nuclear option deserves a serious consideration. I am deliberately making this observation based on a global comparison of costs rather than our own cost numbers as there has been some debate on our costing methods.

With this background, I shall now discuss some of the issues which are very commonly talked about and which must be addressed if we have to adopt nuclear energy. We must first satisfy ourselves as to where we stand *vis-a-vis* these issues and whether we have satisfactory answers to them.

Issues Related to Nuclear Power

Generally the apprehensions about nuclear energy fall in the following categories, (i) Can a nuclear reactor explode like a nuclear bomb? (ii) What would be the impact in a worst accident. Accidents do take place and really one cannot say that no accident will take place. One would like to know what is the likely impact? What is the likely effect on the nearby environment? (iii) The question of routine emissions from the nuclear power plant has to be dealt with. Nuclear power plants do not emit any other pollutant but they do release some radioactivity. What is the effect of these releases on the environment? (iv) The problem of long term waste has to be satisfactorily tackled and answered. Let us discuss these issues in detail.

A nuclear power plant is basically no different from a thermal power plant. Instead of burning coal we generate heat through fission reaction. That heat is transferred to the turbogenerator in much the same way as one transfers steam in a coal fired thermal unit. Electricity produced is then sent to the grid. The difference lies in the manner of producing heat and so let us look at the fission reaction itself. Basically it is like any other chemical reaction. You burn coal and generate energy, similarly you fission atom of uranium and generate energy. Just as you control coal-boiler by either adjusting the input of coal or the input of air or oxygen, in a nuclear reactor you do so by adjusting one of the constituents, the neutrons. The fission reaction generates neutron which is recycled back into the system and if you have a control mechanism which is a modulator and which will

alter the population of neutrons depending on the need, you can operate the reactor at different power levels. If you are maintaining the power level, you are essentially returning one neutron back per fission reaction. Rest of them are absorbed in the reactor material without causing fission. You thus maintain the reactor critical. Should you return more than one neutron, this will increase the neutron population and consequently the power and make the reactor super-critical. If less than one neutron is returned, the reactor becomes subcritical and will be shutdown.

The configuration of a nuclear power reactor is such that the time constant of this chain reaction or the reactor period is relatively large. Even with the shortest possible reactor period, it is impossible to reach an explosive level. All that it would lead to is to generate a lot of heat. One has to consider the effect of this heat in terms of dynamic equilibrium. I shall deal with this problem a little later, but there is no way the reactor will explode. You cannot accelerate this reaction with the kind of rapidity which is required for an explosion. Of course, in all Indian reactors (Pressurised Heavy "Water Reactor : PHWR), there are two independent shutdown systems. So, if there is a problem, in addition to the control mechanism we have two separate systems which are automatically activated in the reactor and which cause absorption of all the neutrons. As a result the reaction is halted and the reactor is shut down.

Then there are inherent characteristics which would shutdown the reactor just by way of increase in the temperature and the physical phenomena that come into play as a result of increase in temperature. What then is the problem with regard to nuclear safety? The answer lies in the two fission products which come out in a fission reaction. The fission products are radioactive and they generate both radiation and heat. To stop radiation we put shield and in that one would expect nothing to go wrong. To remove heat one can either adopt an active system which has been more popular and is more economic, or one can adopt a passive system by having a large pool of water and making sure that it enters the core and circulates based on the natural phenomenon of thermo-syphoning. During normal operation, the cooling is done at high pressure and under shutdown condition at near atmospheric pressure (long-term). As long as it is ensured that the fuel is kept cool and the heat generated is removed while going through transition from high pressure cooling to low pressure cooling and then onwards, there is no way there will be large scale breach of the fuel. The fission products that are contained in the fuel will remain trapped inside. So the accidents that one

talks about in a nuclear reactor arise on account of cooling crisis which in turn lead to some rupture of fuel sheath and a certain amount of radioactivity coming out of the fuel. Typically, a fuel bundle in a PHWR is a half-metre-long assembly. One thing which we must appreciate is that this bundle configuration, when the bundles come out of the reactor, is exactly the same as it was when it went in and all the contents remain within its sheath. Thus, it is only a problem in cooling which can lead to failure of the fuel bundle as a result of which partial release of radioactivity may take place. Otherwise, the fuel bundle comes out and is transferred to the spent fuel storage pool and later processed all in a well contained manner.

The design safety features make provisions for systems which prevent an accident from developing essentially by way of lot of redundancy—redundancy in the control system, in the pumps which cool the system, in the shutdown system as mentioned earlier and so on. In spite of this if an accident takes place, there is an additional mechanism/route for cooling called the Emergency Core Cooling System (ECCS). When the normal cooling fails the ECCS would come on and ensure that the damage that would be caused is minimised. In spite of this, if some activity comes out, then there is the containment to prevent its release into the public domain. A multi barrier arrangement is made to prevent the escape of radioactive materials. As explained earlier the fuel is contained in a sheath which is manufactured to high level of quality. Then there is the boundary of primary heat transport system followed by containment and for our reactors we adopt double containment — a containment and another containment around it. Then, we also have exclusion distance, an area around the plant upto a distance of 1.6 km which is fenced so that nobody goes there except the people who have something to do with the reactor by way of its operation or maintenance. Then of course, we have emergency preparedness plans which I think should be there for all large energy systems or for that matter all systems where there is a certain amount of potential for hazard. This is a well instituted scheme as far as nuclear reactors are concerned. Thus, to ensure safety in nuclear reactors we have

Redundancy

Engineered Safeguards (ECCS, etc.)

Containment

Exclusion Zone

Emergency preparedness plans

Thus, with such multiple echelons of defence, the chance of an accident taking place is made extremely small and there is adequate protection of public and environment in a worst accident in a nuclear power plant.

Let us now look at the statistics right from the inception of atomic energy, total human experience from 1944-88. This data not only includes accidents related to energy generation but also accidents related to man-made radioactive sources and all other spheres of utilization of Atomic Energy (Table II). The total number of accidents have been 296 out of which reactor accidents were 8, in spite of 17-18% of electricity generation by nuclear means. Total casualties have been 69 and the corresponding figure for thermal or hydro would be orders of magnitude higher. Then there is the question of radiation exposure. Such accidents are also listed in the table. There have been some significant exposures and sometimes because of the accidents it has been necessary

TABLE II

Major Radiation Accidents World-wide Human Experience 1944—March 1988[a]

No. of Accidents	*Persons Involved*	*Significants*[b] *Exposures*	*Fatalities (Acute Effects)*
294	1371	633	37
(1)	(1,35,000) (237)[c]	(24,200)	(28)
[1]	[244]	[20]	[4]
296	1,36,615	24,853	69

(8 Reactor Accidents)

a : Source Deo-Reac/ts Radiation Accident Registeries
b : Usdoe/NRC Accident Dose Criteria
c : > 100 rad.

() : Chernobyl Data
[] : Goiania Brazil Data

to replace people. This causes a fair amount of psychological shock and that needs to be addressed properly. Regarding the number of persons exposed, it depends on the kind of numbers used as permissible threshold. In Table II two sets of numbers are listed for the Chernobyl accident, one is 24,000 which refers to a very low threshold but this number reduces to 237 using 100 rads which could cause significant radiation injury. Considering the total contribution made by atomic energy in terms of 17-18% global electricity

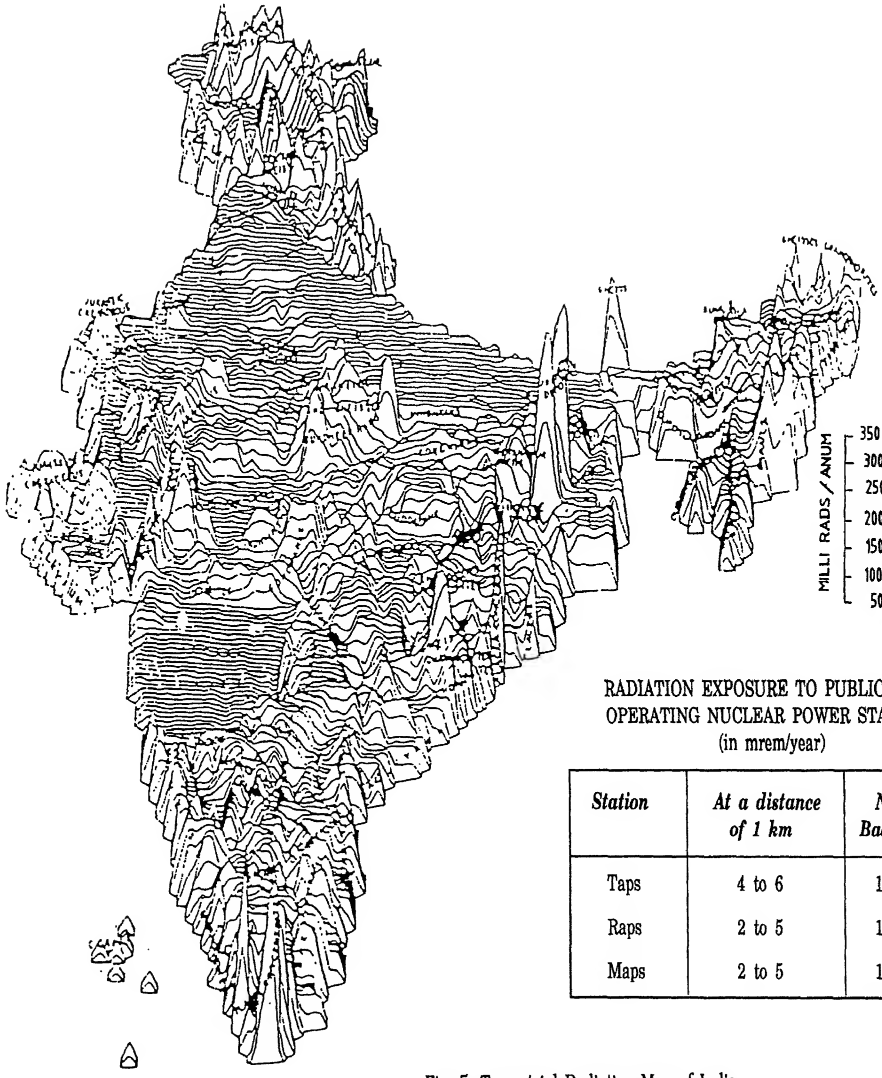
generation and large number of other peaceful applications, these risks are definitely small and should be considered acceptable particularly in comparison with other options.

Routine Releases

Operating power plants do release some radioactivity routinely. Fig. 5 shows the terrestrial radiation map of India. This shows that natural radiation level to which all of us are exposed can vary from 50-60 units to 300-400 units or even higher. On the average the natural background radiation is 100-200 on the same units. As compared to that, the contribution of a power plant is 5-6 units in fact a very small fraction of natural background. It is even smaller than the variation observed in the natural background radiation. Now let us compare this with the standards one uses for chemical pollutants like sulphur dioxide. The international standards for permissible SO_2 levels are much above the average natural levels whereas the international standards for radiation are such that they do not allow it to go much above the prevailing average natural background radiation levels.

Disposal of Waste

We now come to the generation, handling and disposal of radioactive wastes. Most of the wastes generated in the nuclear fuel cycle are low active wastes and their handling and disposal poses no problem as they are handled just like other wastes and dispersed. For the medium level wastes the techniques of dilution and decay are used and they also pose no serious problem. The controversy we come across regarding nuclear wastes concerned high level radioactive wastes which require special technology to handle and long term solution to their disposal. These wastes are essentially contained in the fuel discharged from the reactor after burning. Table III compares the inputs and the wastes generated in a nuclear power plant and a thermal power plant. It will be noticed from this table that 1000MWe NPPs produce less than 1tonne/yr waste as compared to hundreds of thousand tonnes per year produced in TPPs. No doubt the toxicity levels are vastly different but the point is that even in a large programme of say ten such units, over a period of 30 years, less than 300 tonnes of such waste would be produced. Moreover, we have the technology to handle it. Fig.6 is a flow chart showing the handling, storage and final disposal of these wastes. The spent fuel discharged from the reactor is first kept in an interim storage pool which is within the reactor premises itself. It is then sent to the reprocessing unit where the wastes are separated and stored before shipping to a vitrification unit for immobilisation



RADIATION EXPOSURE TO PUBLIC FROM OPERATING NUCLEAR POWER STATIONS
(in mrem/year)

Station	*At a distance of 1 km*	*Natural Background*
Taps	4 to 6	100 to 200
Raps	2 to 5	100 to 200
Maps	2 to 5	100 to 200

Fig. 5. Terrestrial Radiation Map of India.

TABLE III

Comparison of Inputs and Wastes

	1000 MWe Nuclear Power Plants	1000 MWe Thermal Power Plants
Inputs	120 T/Yr Uranium	3.8 Million Tonnes coal Per Year (≈ 11000 T daily)
Waste Products	<1 T/Yr. In Fuel	7000000 T/Yr. CO_2 45000 T/Yr. SO_2 20000 T/Yr. NO_x 1500000 T/Yr. ASH

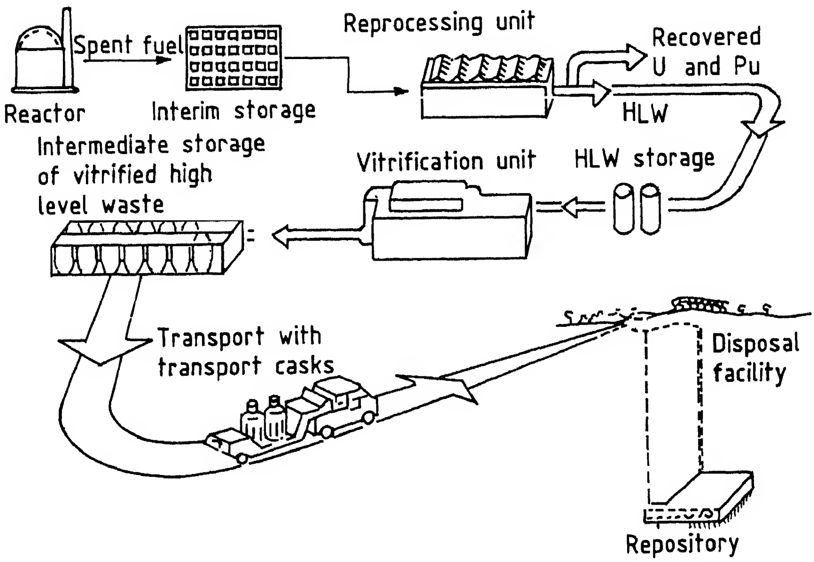


Fig. 6. Reference Route for the Treatment of Spent Fuel and High Level Waste (HLW) Disposal.

in a glass matrix. The vitrified wastes are filled/enclosed in special casks and are stored in an intermediate facility specially made for storage before they can be finally disposed in a repository. We have mastered this technology and have full capability in this area. In fact India is among the few countries who have mastered the full nuclear fuel cycle, technology-wise. Because of small quantities that are involved there is considerable time before our needing to open up a repository. Studies are on and I am confident that it would not be difficult for us to get into that kind of operation when the need arises.

The next question is having stored these wastes, what kind of problem can they pose for us? The answer to this question is provided by nature which has safely contained the waste arising out of a natural reactor which operated at Gabon in Africa long time ago.

Conclusion

Nuclear power thus provides us with a viable option based on our own natural resources. We are self sufficient in this technology and it offers the maximum protection of the environment. As a matter of fact there are signs of many countries reconsidering nuclear option on the basis of environmental concerns.

DISCUSSIONS

Q. The figure for biomass is very low. I do not know on what basis the figure was arrived at. I somehow find it difficult to accept that figure because biomass is not something of an exhaustible type, it is something which you generate annually.

A. I picked it up from a paper in the last conference of INEA. It is based on 20% of total waste land being used for energy plantation, that is what the paper says. The energy potential amounts to 48000 MWYr.

Q. The point is that according to National Sample Survey the annual consumption of fuel wood is of the order of 150 million tonne per year. Now this is not the only annual consumption. This does not include crop residual. When you talk of biomass you are dealing with not merely prime wood, you are dealing with crop residual, rejects of various kinds and whatever. If you take the capital stock it is a much larger figure and it is a renewable figure.

A. Yes, we should take all this into account and also the other modes of consumption of biomass.

Q. What is the capacity of Rajasthan units? I have not heard 235 MWe being produced there.

A. Rajasthan power plants are 220 MWe units and not 235 MWe units and this accounts for the electricity produced plus steam produced. I do not have the exact figures but RAPS-2 does operate close to 220 MWe. RAPS-1 of course had a problem in one of its end shield and currently operates at 50% power.

Q. If they are 220 MWe then it is alright. To what extent plans for setting up 10,000 MWe nuclear are likely to be realised by the year 2000?

A. To me it looks that of the seven reactors which are already under construction, Narora-2 and also Kakrapar-1 would go on stream fairly soon. Narora-2 may go on stream this year itself and Kakrapar early next year. Other five units would get on stream progressively. I also understand that sanction for two 500 MWe units has been obtained. But the question is where is the money? Sanction for a much larger number of units had been obtained for taking advance action. But in the absence of project sanction you canot even proceed. Whatever projects have been sanctioned, I am quite sure they will be completed before the year 2000. But that number still does not make up 10,000 MWe.

Q. Mr. Chairman, I want to comment on the discussion on hazards of incidents. You mentioned Chernobyl and the Brazilian incident. From the point of view of public you gave "how many deaths occurred and how many people were involved". But, the global impact of this is what the public is afraid of and it could be compared, I suppose with Mr. Saddam Hussain's burning of the oil wells and the spread world over of sulphur dioxide and so on and so forth. But, what the public is afraid of is that this hazard continues and has genetic overtones and affects succeeding generations also. So it is really hard to actually give exact facts and figures but I agree with this that this (nuclear energy) is probably as safe as anything else.

A. I would only like to make a comment. For example, emergency preparedness at Chernobyl was such that as a result of the emergency action there, a large number of people were displaced. But a recent study and the investigation that has been done, in fact say that the criterion adopted for relocation of people around Chernobyl - was roughly 1/5th of what is required in accordance with International Commission on Radiological Protection (ICRP) or World Health Organisation's requirement. If they had adopted a somewhat higher criterion for relocation of people, the total number of people displaced would have been much smaller. Now this is important from the point of impact on the public mind. When you displace a large number of people, there are effects which are psychological effects and medical effects which arise as a consequence. They are not necessarily linked with radiation. But they are linked with

psychological and social factors. When you force a large number of people to change their life style and do not feed meat, do not feed milk and that kind of thing and may be go on like this for 6 months, 9 months, it would certainly have its effect on their psyche. That was the kind of problem and that has shown up in a fair measure. So I think it is fear of radiation rather than radiation itself that has done greater damage. Look at the consequence profile of Chernobyl *vis-a-vis* Bhopal and I think the psychological factor when it comes to radiation accident is much more dominating.

NON-CONVENTIONAL ENERGY CONVERSION SYSTEMS

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Introduction

Active work in the area of non-conventional energy sources has been going on in India for the last fifteen years and commendable progress has been achieved. However, it is by now well recognised that non-conventional energy sources can play a significant role in the national energy scene only if they contribute to the generation of a reasonable part of the electrical power requirements of the country. The five power systems which show promise of generating power in the megawatt range are:

a) Solar thermal-electric plants
b) Biomass-based electric power stations
c) Wind farms
d) Small hydro-electric power plants
e) Tidal power stations.

These systems are suitable for the Indian scene and for being connected to the grid. In the following sections, some descriptions of the systems along with their economics and potential are given.

Solar Thermal-Electric Power Generation

Solar thermal power cycles can be broadly classified as low, medium and high temperature cycles. Low temperature cycles work at maximum temperatures of 100 °C. The earlier plants used flat-plate collectors, while the current technology is based on the use of a solar pond. Medium temperature cycles work at maximum temperatures upto 400 °C and use the line focussing parabolic collectors technology. High temperature cycles work at temperatures above 400 °C and use either paraboloidal dish collectors or central towers.

Among all these technologies, the line focussing parabolic collector technology working at a temperature of about 400 °C has proved to be the most cost effective and successful so far. The first commercial plant having a capacity of 14 MW was set up in 1984[1]. Since then, six plants of 30 MW capacity each, followed by a seventh of 80 MW have been installed and commissioned. All these plants have been set up in California, which now has a total installed capacity of 274 MW. A schematic diagram is shown

in Fig. 1. The collector array for this plant has an area of 464,340 sq.m. The cylindrical parabolic collectors used to have an aperture of 6m and have their axes oriented north-south. The absorber tube used is made of steel and has a specially developed selective surface. It is surrounded by a glass cover with a vacuum. The concentration ratio is approximately 80 and the collectors heat a synthetic oil to 400 °C with a collector efficiency of about 0.8 for the beam radiation. The synthetic oil is used for generating superheated high pressure steam which executes a Rankine cycle. In order to obtain a cycle efficiency of about 0.3, both reheat and extraction are necessary. The plant generally produces electricity for about 8 hours a day. The installed cost of this type of plant has reduced over the years because of the increasing installed capacity. The first plant of 14MW is reported to have cost Rs. 81,000 per KW, while the latest 80MW plant is reported to have cost Rs. 52,000 per KW. The current generating cost of electricity is between Rs. 1.50 and Rs. 2.00 per KWH.

The Indian experience with this type of technology has been restricted so far to a small 50KW capacity experimental plant installed at the Solar Energy Centre of the Department of Non-Conventional Energy Sources. A feasibility report for installing such a plant with a capacity of 30MW in Rajasthan has also been prepared. The report indicates an installed cost of only Rs. 35,000 per KW and an average cost of generation of Rs.1.26 per KWH. Both these estimates appear to be a little optimistic in comparison with the international data.

Biomass Based Electric Power Stations

The technology of biomass-based electric power plants is well established in USA and Europe and there are over 500 such plants generating power in the range of 5 to 50 MW. These plants use wood, wood-waste and various types of agricultural waste. In India, a few sugar mills run their own power plants using sugar can bagasse to meet internal demands of steam and electricity. Almost all these plants run at a low efficiency with outdated technology. There are plans for setting up a 10 MW plant in Punjab using agricultural waste in the form of rice hulls. A techno-economic feasibility study for setting up a 10MW station on a commercial basis in Western Maharashtra is also nearing completion[2]. Some details of this study are as follows:-

The annual fuel requirement for the plant has been estimated to be 73,000 tons (dry). This requirement could be met either by agricultural residues

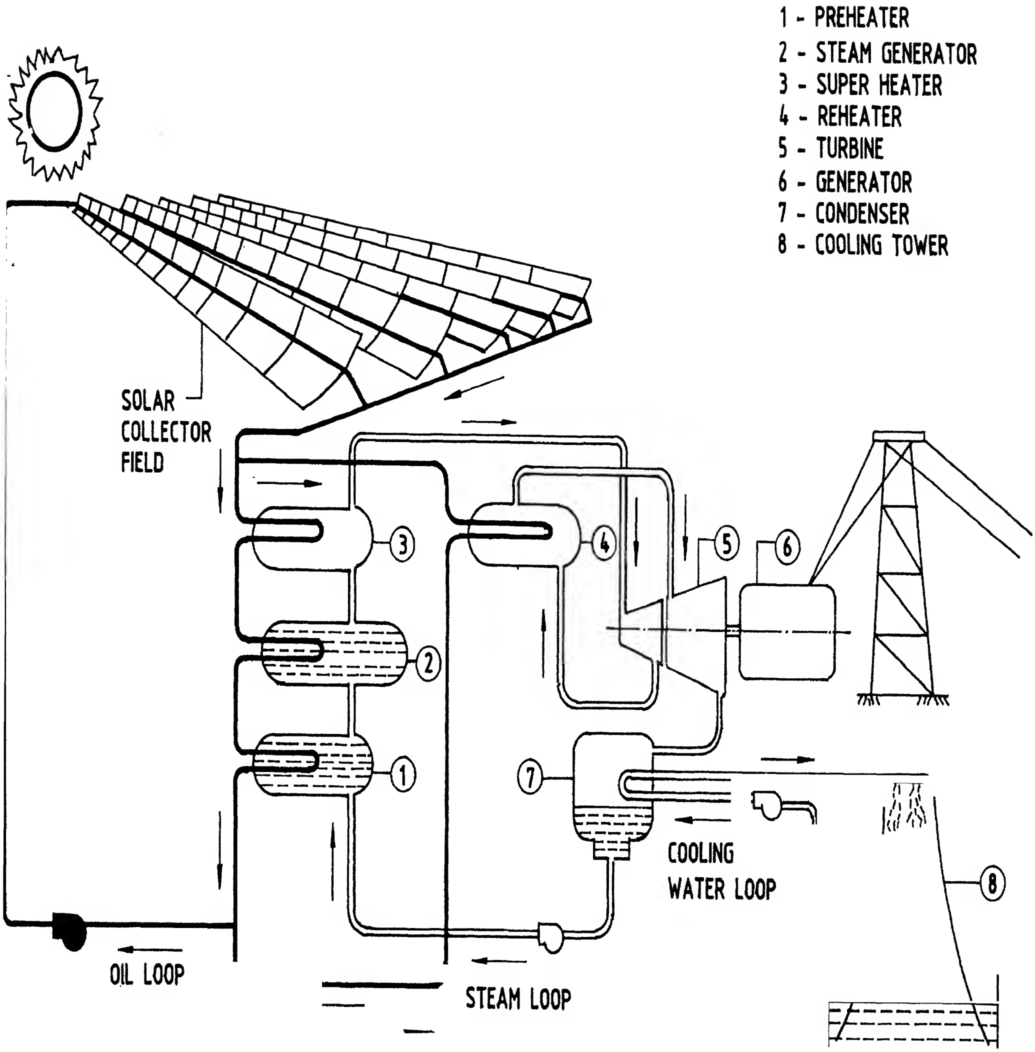

Fig. 1. Solar Thermal-ELectric Power Station

(from sugarcane, bajra, wheat, etc.) or through large scale energy plantations. Depending upon the availability of residues, two scenarios have been considered. In the first scenario, it is assumed that the entire fuel requirement will be met by the agricultural residues, while in the second scenario, it is assumed that only 25% of the annual fuel requirement will be met by the residues and the remaining 75% will be met by growing biomass in energy plantations. The tree species recommended are leucocephala, eucalyptus, juliflora, etc. These would yield 25-30 tonnes/hectare-year on good soils and 10-15 tonnes/hectare-year on the poor soils with irrigation available. All these species will be grown with a coppicing cycle of 5 years. It is estimated that depending on the soil condition, 1800 to 3600 hectares of land will be required for the energy plantation.

As far as the power plant technology is concerned, the conventional Rankine cycle with a steam turbine is considered to be most appropriate. The power plant would have a boiler with a travelling grate generating approximately 50 tonnes of steam per hour at pressure of about 40bar and a temperature of 400 °C. The overall plant efficiency would be approximately 30 per cent. It would cost approximately Rs. 60,000 per KW.

For the first scenario with the biomass (in the form of agricultural residues) priced at Rs. 400 per ton, the electricity generation cost is estimated at Rs. 1.50 per kWh. For the second scenario, the cost of electricity generation is estimated at Rs. 1.70 per KWH at a wood price of Rs. 650 per tonne and a residue price of Rs. 400 per tonne.

Wind Farms

In the last few years, wind energy has emerged as an attractive option in any future energy supply scenario. Technologies for harnessing wind energy on a large scale have matured and possibilities exist for wind power to meet peak demands in certain areas. The wind machines being used for electricity generation generally have a three or two blade horizontal axis propeller type of rotor and are manufactured in a wide range of ratings from 50 to 200 kW. A large number of these machines are erected side-by-side and constitute a wind farm. The main components of a wind machine are the tower structure, the rotor, the nacelle and the control unit. The tower is meant to keep the rotor and nacelle at a certain height above ground level where the wind speeds are higher. The rotor consists of two or three blades with aerofoil sections joined to the hub. They are usually made of FRP. The nacelle contains all the main machinery, i.e. transmission, brake

mechanism, generator, gear box, etc. The major functions of the control unit are protection and regulation of the system.

The total installed capacity of wind farm installations in the world is around 1500 MW. Of this, nearly 90% (1300 MW) is installed in California. During 1987, the wind farms there generated 1727 x 10^6 kWh with an annual capacity factor of 16%. Wind project costs have declined significantly from Rs. 35,000 per kW in 1985 to Rs. 15,000 to Rs. 20,000 kW in 1991.

The Indian wind energy programme for electricity generation began in 1986 with the commissioning of five small wind farms along the coast line at Mandvi, Okha, Tuticorin, Deogad and Puri having a total capacity of 3.3MW. The capital cost of these installations was Rs. 5.5 crores (i.e. about Rs. 17,000 per kWh) and the cost of electricity generation has varied from Rs. 1.00 to 2.0 per kWh. The specification of a typical machine at these wind farms are as follows :

Rotor	–	Diameter	16m
		Rotational speed	37 to 47rpm
		Number of blades	3
Blades	–	Material	Glass fibre reinforce polyester
		Aerofoil	NACA 4415
Tower	–	Height	23.4m
Generator	–	Type	Induction
		Rating	55 kW
		Voltage	415 VAC
		Rotational speed	1035 rpm
		Frequency	50 HZ
Operational data	–	Cut-in wind speed	3.5m/s
		Rated wind speed	12.5m/s
		Cut-off wind speed	25m/s

Subsequent to the installation of the above wind farms, about 5MW of capacity has been added and work is in progress to install another 13 MW at other locations in the country.

The potential for wind farming in India is still to be properly assessed. However, rough estimates indicate that the potential is at least 20,000 MW.

Small Hydro-Electric Power Plants*

Since independence, a number of large scale hydro-electric power projects have been taken up in the country and most of the present built-up capacity of 20,000 MW is based on large and medium scale plants. However, increasingly large, hydro-electric projects are being viewed with considerable alarm from the environmental view point and many believe that the establishment of large multi-purpose schemes/for irrigation and power may be reaching a point of diminishing returns. It is in this context that a more vigorous approach towards the installation of small hydro-electric projects is called for. Technologies for manufacturing turbines and generators in this range are available in the country, and in many states suitable sites have been identified.

According to the definition of the Central Electricity Authority, hydro power projects having installed capacities in the range of 2 to 15MW are classified as 'small'. It is estimated that the potential for such plants is at least 5000 MW. The total number of small hydro-electric projects in operation in 1988 was 89 with an installed capacity of about 170MW. Another 87 projects with an installed capacity of 199MW are under construction. Thus, there is a clear case for exploiting this resource. The installed cost for a small hydro-electric power project ranges from Rs. 20.000 to Rs. 30,000 per kW. Although this cost is more than that for a large project, it should be noted that small hydro-electric projects take only 2-3 years to be installed compared to 8-10 years for large projects.

Tidal Power Stations

Tides are generated primarily by the gravitational attraction between the earth and the moon. They arise twice a day. In mid-ocean, the tidal range is only about one metre but in some coastal estuaries, it is much greater. This is due to the amplification of the tidal wave as it moves up the narrowing channel of the estuary. Basically, in a tidal power station, water at high tide is first trapped in an artificial basin and then allowed to escape at low tide. The escaping water is used to drive water turbines which in turn drive electrical generators. A schematic diagram is shown in Fig. 2.

Based on information available at favourable locations, it is estimated that a capacity of 64,000MW can be harnessed by tidal power all over the world. The first commercial tidal power station was constructed in France

* It is a matter of debate whether small-scale hydroelectric power should be classified as "non-conventional." Many persons classify hydroelectric power plants (large or small) as conventional.

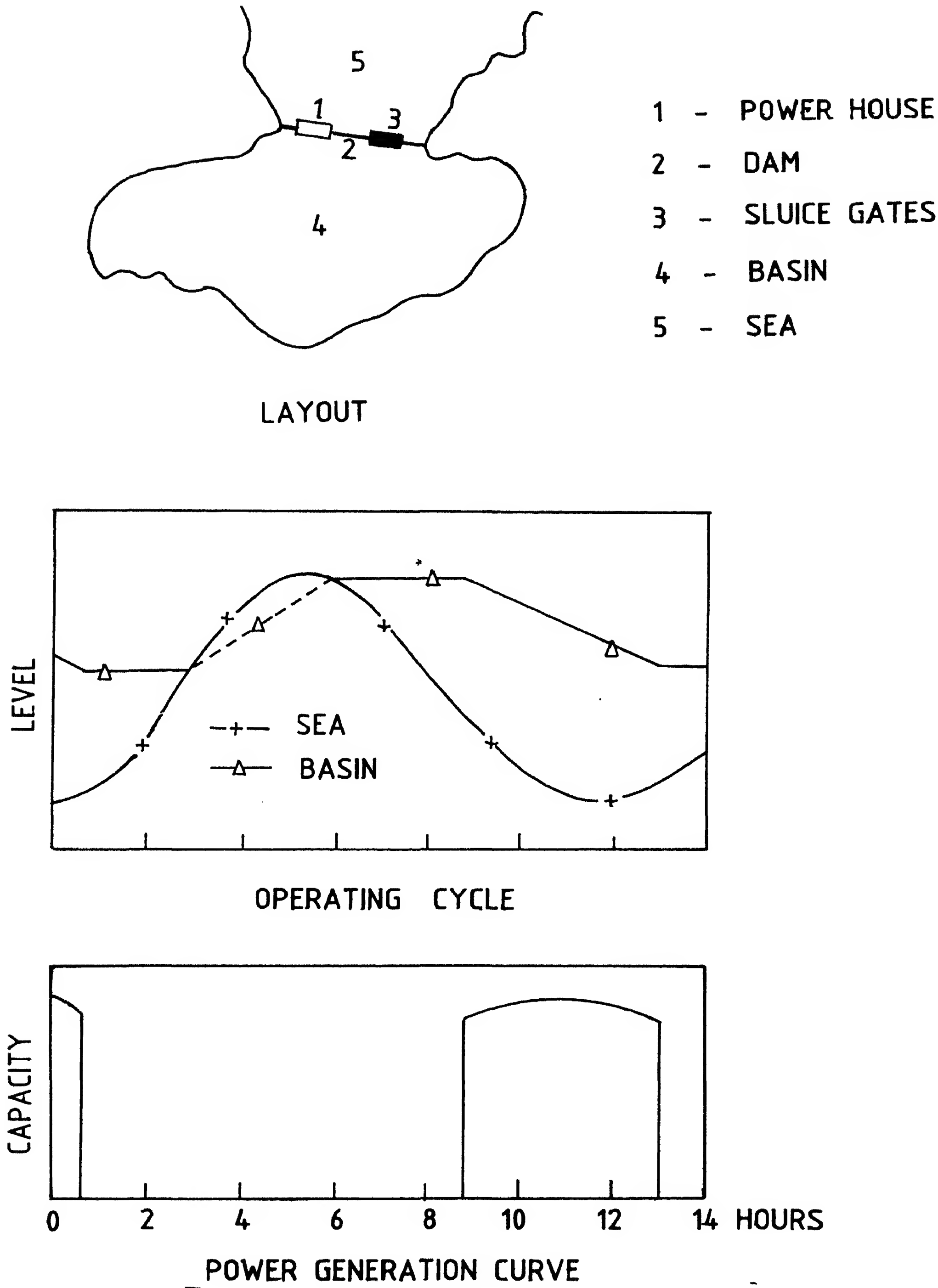

Fig. 2 Tidal Power Station—Single Basin Single Tide Operation

in 1965 across the mouth of the La Rance estuary. It has a capacity of 240MW. The average tidal range at La Rance is 8.4m and the dam built across the estuary encloses an area of 22sq.km.

Despite having a long coast line, only three potential regions have been identified in India. They are

- Gulf of Kutch
- Gulf of Cambay
- Ganges delta.

The variation of the tidal range at four sites in these regions is given in Table I.

TABLE I

Variation of the Tidal Range at Four Suitable Sites in India

	Spring Tide Range (m)	*Neap Tide Range (m)*	*Average (m)*
Bhavnagar (Gulf of Cambay)	10.29	3.60	7.00
Navlakhi (Gulf of Kutch)	7.17	3.74	5.45
Kandla (Gulf of Kutch)	6.32	3.68	5.00
Sagar (Hooghly Estuary)	4.71	1.40	3.06

The figures in Table I indicate that there is scope for developing tidal power plants at these sites. Large scale plants are possible in Kutch and Cambay, while only small scale plants can be developed in West Bengal. Preliminary plans have been drawn up for a 600MW tidal power plant in the Gulf of Kutch. However, indications are that the initial cost is high and may exceed Rs. 80,000 per kW.

Small Capacity Power Systems

It would be useful to mention that a number of small capacity power systems using non-conventional energy sources have been developed in recent years. The following is a partial listing of such systems :

(1) Solar photo-voltaic systems
(2) Biogas driven gensets
(3) Biomass gasifier based gensets
(4) Mini/micro hydel power plants
(5) Single wind electric generator systems.

In general, these are stand-alone systems which generate power in kilowatts and are suitable for remote locations. For this reason, they have not been discussed in any detail in this paper.

Concluding Remarks

The cost estimates given in the earlier sections for the five power systems are presented in consolidated form in Table II.

Keeping in mind that the installed cost of power from conventional energy (large hydro, coal, etc.) ranges from Rs. 15,000 to Rs. 20,000 per kW., it is clear that the non-conventional energy systems discussed can be considered to be promising. Also, it is to be noted that in most cases, the cost has decreased in recent years with increased volume of production.

TABLE II

Cost Estimates for Various Non-Conventional Energy Conversion Systems

System	*Installed Cost Per k/W (Rs.)*	*Generating Cost per kWh (Rs.)*
1. Solar thermal-electric (Line focussing)	52,000 86	1.50 to 2.00
2. Biomass-based	60,000	1.50 to 1.70
3. Wind	15,000—20,000	1.00 to 2.00
4. Small hydro	20,000—30,000	—
5. Tidal	80,000 (?)	—

It would appear prudent therefore to recommend some sizeable investments in the next ten years in each of the systems described. The advantages of making these investments are that the country would obtain good operating experience with such systems and learn to adapt them to Indian conditions. On a conservative basis, it appears desirable to install a total capacity of at least 500MW by the turn of the century (about 100MW in each of the five power systems). This investment would cost approximately Rs. 2000 crores.

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DISCUSSION

Q. Could you kindly tell us the state of the art in the solar power system (SPS)? Solar concentrators *vis-a-vis* line collectors !

A. The technology that has been the most effective so far and also cost effective is line focussing type of collectors; that is why I mentioned that it has been commercialised and its cost is about Rs. 1.5 to Rs. 2 per kWh.

Q. The Department of Energy in the US are concentrating on a solar power system which will depend on 3 Geo-stationary satellites which would convert the solar energy into micro waves : an antenna will convert the micro wave energy to DC power and then through an invertor system, connection will be made to the grid. Would you kindly throw some light on what is going on, or have they stopped this?

A. That is all in the conceptual stage. Feasibility studies only have been done, nothing of that type has been built.

APPLICATIONS OF PHOTOVOLTAIC CELLS

Brig. M.R. Narayanan
Chairman and Managing Director
Central Electronics Limited

I thank Professor Sukhatme for pleading the case of the non-conventional energy sources. And I would like to, during the next 5 to 10 minutes, give some thought to this particular energy system. Well, he did cover the solar photovoltaic system, but summarily rejected that saying it may not be able to generate power of the order of a few megawatts to feed the national grid. But at the same time, when we talk in terms of our country and when we go to the far flung areas, remote and inaccessible areas, I find that there is no other alternative but to go in for solar photovoltaic systems. It may not be in terms of say hundreds of megawatts but definitely we can talk in terms of a few kilowatts to one megawatt. I will try to give an idea of various application areas of this energy source. The application areas of the solar photovoltaic system can be divided into categories: (1) essentially rural based requirements; (2) the industrial; and (3) bases of paramilitary forces in remote areas. As regards rural bases requirement, there are a number of applications and I will demonstrate through examples.

In a typical Rajasthan village called Bhakarwala we have gone in for water pumping system for drinking water where the water level is as low as about 100 meters at a straight depth. We have used special submersible pumps powered by solar voltaic energy. The solar panel is 2-3 kW and the pump is a special submersible type. As soon as the sunlight comes out 6 : 30 to 7 in the morning — the water automatically starts flowing and local people have got adjusted to it. We have installed 90 such systems all over the country, particularly in regions like Rajasthan, Madya Pradesh, some areas of Uttar Pradesh, Tripura, Nagaland, Manipur and also Arunachal Pradesh. So, this is definitely a tremendous application and our experience is that even villagers themselves come forward. This was especially seen in Rajasthan after we had set up a water pumping system and demonstrated its utility. In many villages, a number of people come enquiring about to take advantage of this water source.

Next application is street lighting as well as domestic lighting, especially in far-flung remote villages. We have used 60W lamps for this purpose and the villagers are very happy. In Tamil Nadu, for the National Adult Literacy

mission, we have provided lights in the class rooms which have 50-80 wards. Last year we had 1200 such systems all over the country, in remote areas like Meghalaya, Mizoram, Nagaland, Arunachal, etc.

Another major application especially for the village industry is for national immunisation mission. The low power DC compressor based refrigerators for storing vaccines and other essential medicines are a boon to the mission. In U.P. last year we did a pilot project, at about 10 sites and this year we are doing at 25 to 30 sites.

Another application of solar photovoltaic is the multi-access rural telephone and rural radio telephone. Now you must be aware that almost every village is going to get telephone. Based on this mass requirement, last year we supplied about 1000 such systems and this year we have supplied 4000 systems. There is a DOT tender for 20,000 systems for the extended integration of the country with telephones. These are areas where they are totally solar powered. Of course, the power is stored in the battery and that is adequate power for very low watt, low power application. Then there is the very low powered transmitter (LPT) for Doordarshan. Doordarshan has been able to extend to the remote village and remote corner of the country, because of this LPT and they are totally solar powered. We have supplied very large number of such systems. Of course, they have battery back up. A solar photovoltaic system was installed at a village in Leh in 1981 and has been functioning there for the last ten years. This village is actually about 80-90km away from Leh. There is a community hall as well as a school. This was put up by us in 1981 and last year I had been there. It has been working very effectively.

A word about the solar panel. Once installed it provides the energy at the site, at the user's premises. Secondly, it is the actual solar panel which can work for 20 years and when we talk in therms of cost comparison it can be realised in the course of only 10-12 years itself. Solar panel has been used on the deck of the off-shore platform where you can't easily use other forms of supply.

The next application is for the observation posts at the airport specially remote one like at Manipur, Aizwal and Tirupati. Solar powered DC systems have been used for the protection of the oil pipe-line.

Another application is that of a warning post oral as well as visual on an unmanned or manned railway crossing. We have a transmitter about 3-4km away and it is solar powered. As soon as the engine actually crosses,

the information is picked up and relayed. It is decoded and we get alarm. Solar power also has defence and radar related application. A portable solar panel was used in one of the early expeditions and we have been using similar panels for critical army and defence applications essentially for charging of battery of the communications radio equipment.

DISCUSSION

Q. Are there any problems related to maintenance of such systems in remote areas?

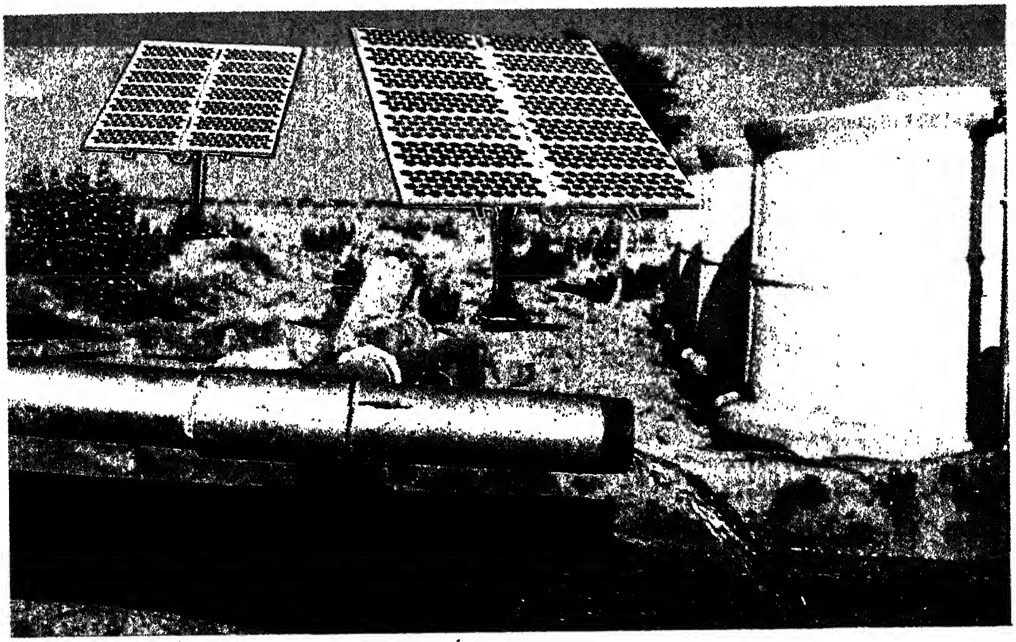
A. It is very correct to say that any of the application systems whether it is solar photovoltaic or solar thermal, the first thing one should have is the acceptability and secondly ensure its working through proper maintenance. The solar photovoltaic system, e.g. consists of 3 distinct parts : the solar panel, the battery (in case they are going to use the battery as a reservoir) and in that case they must have some sort of charge controller. The problem is not with the solar panel. The problems arise because of the neglect of the battery. Now, where the people are totally dependent on this type of system for their power generation, like the example I gave about Leh, there I found that a local mechanic, a Ladakhi, has been maintaining it so well for the last ten years that it was an absolutely pleasant experience when I went there. The chap was talking in some local English and Hindi and he was so happy and all those people came around us. He showed me the batteries and said, "Sir, see the terminals". Beautifully maintained ! He said, "Sir, I do not touch it for at least a month or two at a time because I am getting sufficient light." In India we have got abundant sunlight even in a place like Ladakh. But, at the same time, whenever some other source of energy is available, normally people have a tendency to neglect these contraptions. So basically we have got to educate people and once they know that this is their mainstay, they will look after it.

Comment : *Suresh Bajpai (INSA)*

The Government of India has a very big plan for non-conventional energy sources. Although the plan got somehow decelerated during the time oil prices came down, but with Gulf War and the implications thereof, the plan is being accelerated once again. The biomass power that is being planned is about 1200MW for the 9th Plan and by 2000 AD the plan is that it will be multiplied five times i.e. 6000 MWe. Wind power for the 9th Plan is

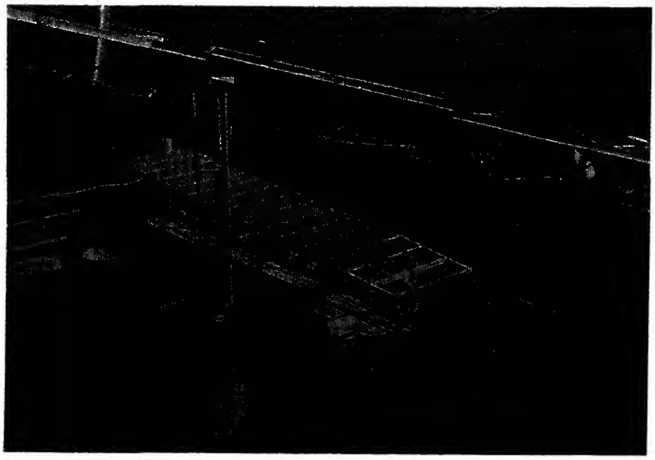
put at 1000MW and during the next five years, the plan is to have five times that, i.e., 5000 MWe. Solar power contribution by the 9th Plan is to be 440MW and by 2000 AD 2000MW. Small size hydro power, as Professor Sukhatme said - whether it is conventional or non-conventional- is expected to be 600 MW for the 9th Plan and 2000 MWe for the year 2000 AD. *Improved chulas* : Professor Sukhatme did not touch upon this aspect of using biomass in a more efficient way. According to Government plans, 30 million improved chulas will be installed in the 9th plan and 100 million by the year 2000 AD; 4 million biogas plants by the 9th plan and 12 million by 2000 AD; energy plantation over 0.75 million hectare by the 9th plan and 2.5 million hectare by 2000 AD; and power from sewage and sludge in the 9th plan and by the year 2000 AD, 15MW and 50MW respectively. Solar thermal systems of energy equivalent to 6 million tons of coal which will be tripled or more than tripled to 20 million tonnes of coal equivalent by 2000 AD will be put up. Similarly, photovoltaic pumps, as CEL has just demonstrated for 4.5MW and 15MW ; Wind pump for 15 MW to 50MW; small battery chargers from 3 to 10MW; Power from distilled wastage from 40-140MW and municipal solid waste from 48 to 160MW, will be realised by the 9th Plan and the year 2000 respectively.

The idea of giving these figures to this august audience is to point out that the Government of India is fully aware of the potential of non-conventional energy sources and the role that they possibly can play in the future energy mix of this country. However, there are certain limitations in non-conventional energy systems and that somebody has to take these into account for planning of a project in non-conventional energy. In the conventional energy source, you have a generator, put petrol there and if it is rated at 1.5 kW, it gives 1.5 kW, provided it is maintained properly. In the case of non-conventional or renewable energy source, the source of energy is the environment itself and that being so, the problem that comes in the non-conventional energy sources is the following. A system is designed, researched, developed and tested, may be inside the laboratory, is installed at a particular site and is then tested for certain time. Then it is believed that it has been perfected. That is where some problems are being experienced. In many of these non-conventional energy systems that have been installed, what is lacking is the proper monitoring over a long period of time. For better performance, this system has to be optimized at the site where it is planned to be installed before a mass scale installation of the system can be considered. So, my submission is, that unlike the non-renewable energy systems, for the renewable energy systems, a lot still need to be done on the system optimisation and also on the public acceptability of the system.



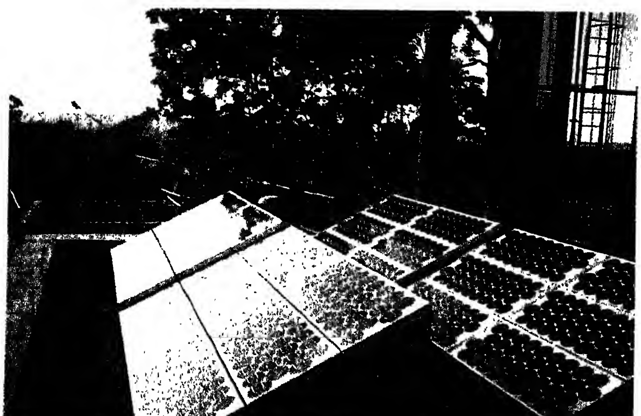
A typical view of SVP deep well water pump installation in Bhakarwala, Bera District, Jodhpur (Rajasthan)

A view of shallow well water pumping system



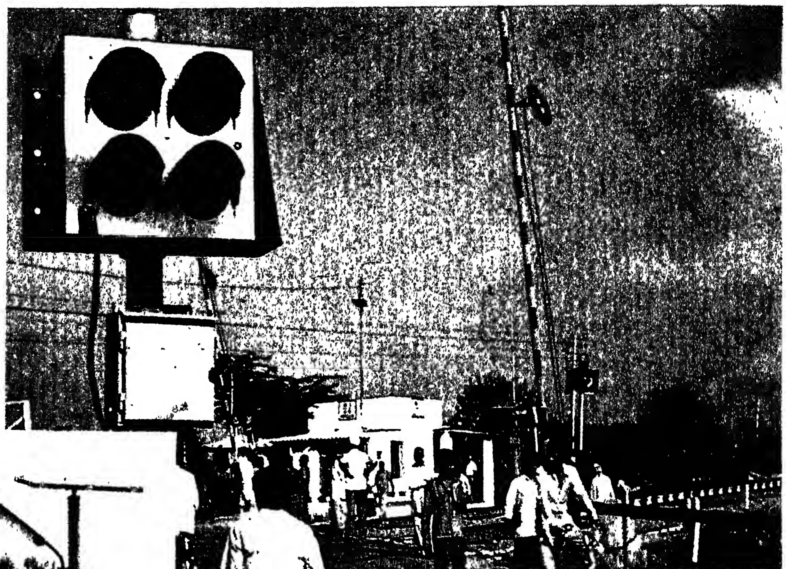
SVP system on unmanned off-shore Oil Well-head Platform

SVP powered obstruction warning light at Khajuraho airport



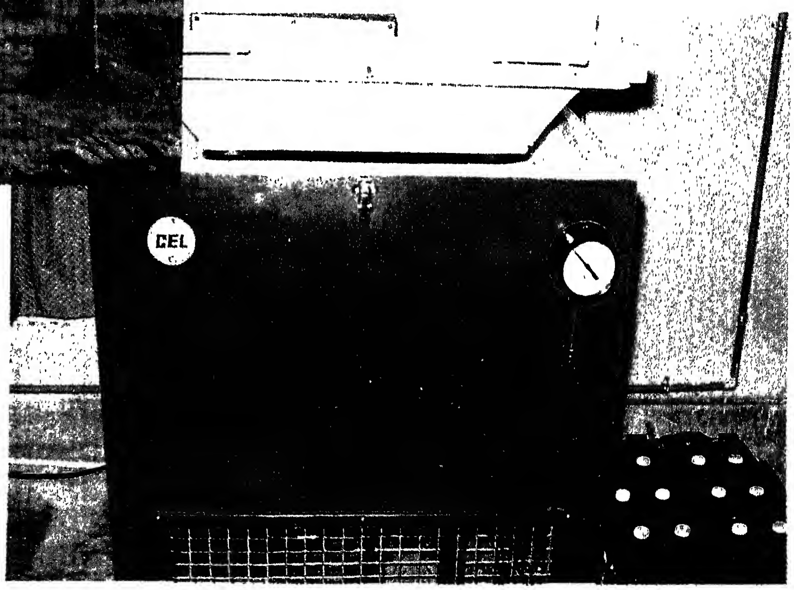
Powered system for very low power TV transmitter

SVP power source for charging batteries of communication equipment on Everest



Audio-visual alarm of "SOLAGARD" at level gate

SVP based stand alone street light system



SVP powered refrigerator for National Immunisation Mission

ECONOMICS OF POWER GENERATION

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PART - I

The close relationship between energy consumption and economic development is well established. This can be readily explained by the fact that energy is an input to practically all human activity. Energy plays a dual role - as an input for agriculture, industry and transport and as a 'private good' in the household sector where it provides services such as heating, lighting and motive power. Studies indicate, however, that on account of constant technological improvements, the energy-GDP elasticity has been steadily declining over time. In the western industrial countries, after the oil shock of 1973 and 1979, structural changes in the economy together with concerted technological effort to improve the efficiency of energy use, have reduced the elasticity to below unity. A decline in elasticity is visible in India also; between 1953-54 and 1987-88, the over all energy-GDP elasticity was 0.86. However, on breaking up the energy consumption into its modern (oil, coal and electricity) and traditional (fuel wood, animal dung and crop residue) components, it is seen that the modern or the so-called commercial sector of energy consumption shows an elasticity as high as 1.46, whereas the share of the traditional fuels is steadily going down. The explanation for the high commercial energy-GDP elasticity lies in the following :-

1. (a) A large part of the increase in GDP originates from the production sectors (agriculture, industry and transport). Both agriculture and industry show growing energy intensity. The transport sector is also a large consumer of energy.

   (b) There is a steady substitution of the traditional by the modern fuels.

   The per capita consumption of energy is low reflecting the existence of pervasive poverty. Any strategy aimed at improving the levels of income and quality of life of the country's poor inevitably entails an increased demand for modern fuels. Sustaining a reasonable rate of growth in a situation where there is a crunch of resources poses a serious challenge.

2. A phenomenon noticed in all countries, developed and developing, is the growing share of electricity in the energy spectrum. In the OECD countries

for instance, the share of electricity which was 20.8 per cent in 1960 is now estimated to be close to 37 per cent. Because of easy transportability and versatility of application, it is replacing less efficient fuels. Moreover, electricity can be generated from both non-renewable and renewable sources. The increasing use of electricity has been a contributory factor to the reduction in the energy intensity of the economy. The picture is similar in India. Of all the fuel forms, electricity shows the highest growth rate. Between 1970-71 and 1987-88, the annual growth rate of electricity consumption was 7.2 per cent as against the GDP growth rate of 3.8 per cent.

3. The development of the power sector cannot be viewed in isolation, but it must be considered as a part of the total energy policy. One of the primary guiding principles of such policy has to be energy security. International oil developments since 1973 have had traumatic effects on global political and economic relationships. When such developments take place in a sudden unpredictable manner, the plans of energy importing countries like India go awry. It is imperative therefore that self-reliance is regarded as a paramount objective in a vital area like energy. The Indian energy strategy has therefore to be guided foremost by its own resource endowments. We have reasonably abundant reserves of coal. Eighty per cent of the hydro power potential is yet to be exploited. No doubt, formidable technical and ecological problems have to be faced. But these two sources have to provide the mainstay for the Indian electricity industry. Though the immediate contribution of nuclear power will remain limited, its exploitation with a view to the eventual harnessing of the abundant thorium reserves in breeder reactors, is important. The oil reserves, both proven and projected, being limited, its substitution, where possible, by coal and electricity, has also to be kept in view. In the recent years, natural gas started playing a role on the Indian energy scene. There is a widespread feeling that we have enormous gas reserves which, if exploited, can provide a neat solution to our electricity problem. The realities are different; even under a highly optimistic scenario of domestic gas production reaching 120-140 million cubic meter/day (M.cu.m/d) after providing for higher value applications such as production of fertilizers, LPG, town gas etc, the available gas may be just enough for 10,000-12,000MW of power generation on open cycle (the gross production of gas averaged about 46 million cubic meters/day during 1989-90 of which about one-third was flared). Considering that even as it is, the annual addition to generating capacity is about 5,000MW, the gas reserves cannot

play a substantive role. As explained later in this paper, new and renewable energy technologies of power generation will make only a limited contribution in the near future. Therefore, India will have to rely heavily on its relatively abundant resources of coal and hydro power to meet future electricity needs.

a) an optimal mix of different sources of electricity so designed as to match the production capability with the varying demand;

b) optimal location of thermal and nuclear power stations;

c) adequate capacity for power transfers; and

d) high operational efficiency, which requires systematic plant maintenances, strict control in regard to fuel consumption, minimum transmission and distribution losses etc. The quality of management of the utility (manpower, inventory and finances) will also obviously have an impact on its performance.

6. A broad-based picture of the economics of different sources of electricity is as follows :-

Hydro Electricity

Water is a renewable source of energy and the process of generation is non-polluting. The cost of generation however varies widely from project to project depending upon whether it has a storage reservoir or whether it is a run-of-river project and also on the available head. The more attractive sites being first tackled, the costs are bound to show a rising secular trend. In most parts of India, hydro-power would be the cheapest option for meeting peak loads. In North-Eastern India, which is rich in both hydro and hydrocarbon resources, natural gas will have an edge. Where good storage is available, a hydro project can be an important source of energy, but such a project faces environmental issues such as loss of forest area and the displacement of human population.

Nuclear Power

Suited as nuclear stations are for meeting base loads the cost comparison has to be with thermal power stations. According to the official documents, nuclear power is cheaper than coal-fired thermal power even at locations close to the coal mines. But, given the low grade of uranium available in India, the high cost of heavy water (as also the high make-up requirement), low capacity factor and uncertainties regarding the cost of fuel reprocessing, waste management and de-commissioning of plants, nuclear power does not seem to be the cheaper option. Nevertheless, the concept of a three-stage development (uranium-plutonium-thorium) envisaged by Homi Bhabha still remains valid and justifies the nuclear power programme in India. The environmental concerns of nuclear power generation arising from radiation

hazards during normal operations as well as in the eventuality of an accident, are well known and need not be elaborated here. One has also to note that the problem of spent fuel storage has not been fully overcome.

Thermal Power

As stated earlier, the Indian power industry has to depend heavily on coal, which is to be the main source of primary energy for the next few decades. Coal based power generation is well suited to meet base load requirement. Some design modifications are being made in the new plants being installed in areas such as Western India with a low proportion of hydro power, to enable them to respond to some extent to varying load conditions. On account of low sulphur content in most Indian coals, the problem of acid rain is not faced in India and there are effective devices for controlling particulate emissions. But, there is a concern the world over in regard to the possibility of a gradual warming up of the earth on account of the emission of green house gases. Fluidised bed combustion (FBC) and coal gasification technologies have been identified as the best answer to this problem. A good deal of R & D effort is necessary before the techno-economic viability of large FBC plants or the suitability of Indian coals for combined cycle gasification plants is established.

Natural Gas

As mentioned earlier in this paper, natural gas could be a supplemental source for thermal power generation. Given its limited availability, it can be established that its use as a source of peak power (not as a substitute for coal to generate base power) will give maximum return to the economy.

PART - III

7. The oil crisis of 1973 and the environmental concerns associated with large power projects have given an impetus to the development of renewable energy technologies. Leaving aside futuristic possibilities (such as fuel cell and hydrogen) and technologies for which there is limited potential in India (such as geothermal and tidal), electricity generation through direct exploitation of solar energy (thermal and photo-voltaic routes), wind power and biomass energy are of interest in the Indian context. These technologies offer several advantages; they can be located close to the areas of consumption reducing distribution losses, they have a relatively short gestation period, the maintenance requirements are not demanding,

capacities can be built up in a modular fashion and they are generally more environment-friendly than conventional large scale technologies. Inspite of these favourable factors, their market penetration has not been substantial in India or elsewhere. The reasons are as follows :-

a) The new technologies cannot cater for large or bulk requirements. In India, urban and industrial loads account for 70 per cent of the electricity consumption. Such loads would have to be catered for by conventional large scale power generation.

b) In the case of grid supply of power, the capital investment right up to the point of consumption is made from the public exchequer. On the other hand, the investment on the decentralised energy supply devices has to be made by private individuals, even though the society benefits in the process. To some extent, the gap between the economic and financial returns can be bridged by subsidies, but the inherent difficulty remains, particularly as the new technologies are characterised by high capital cost (maintenance costs are low).

c) There are some technical limitations also. If a decentralised electricity source operates in the stand-alone mode, the reliability of supply will be low and the capacity utilisation will remain poor. Solar energy and wind energy-based devices may require a backup system because of the variability of the primary source. This will make the system quite expensive. On the other hand, if the decentralised sources are linked with the grid, maintenance of grid stability will pose problems when the proportion of aggregate decentralised capacity becomes significant.

d) The state of art as it stands today: the new technologies are relatively expensive and beyond the reach of most sections of the rural community.

e) Technologies such as solar and wood-based thermal pwer generation are land-intensive. The common property resources in the rural areas have traditionally provided support to the rural poor through the provision of fuel and fodder free of cost. Even as it is, on account of the growing pressure of population, encroachment by powerful landlords etc., there has been a steady erosion of such resources aggravating the problem of the poor. To deprive them of what little is left to generate electricity which is consumed by the affluent sections of the village community is clearly not desirable.

PART —IV

8. It would be apparent from the foregoing account that in the next 20-30 years the country will have to depend primarily on the conventional energy technologies to meet the bulk of its electricity requirements. A new feature would be that, in addition to installed capacity, gas-based plants will have a sizeable share. But in terms of energy contribution, coal will remain the dominant source, over-shadowing the contribution from hydro, nuclear and gas sources. If our scarce financial resources are to be utilised to maximum advantage, much greater attention will have to be paid to demand management and more efficient use of energy. The scale of R & D effort on renewable energy technologies needs to be stepped up. Rather than spread our investments too thinly, we should concentrate on the development of solar, wind and biomass devices, which are particularly relevant for India.

9. There is a wider question. Electricity demand growth depends on the pattern and content of economic growth. Can the Indian scenario be distinctly different from the western model ? This is a question which raises basic issues and merits detailed examination by all sections of the community.

FINAL DISCUSSION

Shri Bhasin: As expected the paper presented by Mr. Satish Chandran was really very fine. I think it covered very many aspects, the various issues involved and touched upon basic things. What a villager needs, our main point, should have been there. He rightly said that it was not essential that we should follow the electricity route. About the demand growth, I have to observe that when we project demand growth for energy, we generally base it on economic growth. If the economic growth rate is less, the electricity growth rate will be lesser. For the year 2020 what we have projected is based on things like: what will be population growth, what is other countries' per capita consumption and what could be ours ? On that basis did we make assumptions for the 9th Plan? But now with the present crunch we feel that it may not be as we expected. Because, if funds for the 8th Plan are lower, consequently the work for the 9th Plan schemes will not be taken up and the 9th Plan outlay will be lower. So, for per capita consumption of electricity, I expected 512 units in the year 2000 AD, but it may not be there, it may be just 400 or 380 units. Consequently, in the year 2020 it may not be 1000 units, it can go down.

Dr. Chidambaram: Regarding the cost of nuclear power - of course, one could have a very long debate on this. As far as heavy water is concerned, it is leased. For the nuclear power plants, they are allowed 12% return on their investment and that is the way they calculate the nuclear power cost: they are also now putting in a term for decommisioning. Doing all that, my friends in the Nuclear Power Corporation tell me that the cost of electricity produced compares favourably with coal - fired stations. Of course, we do not put nuclear power stations on the pit heads but somewhat away from it.

Professor Mitra: Indian National Academy of Engineering, had deliberated on the electricity environment very exhaustively exactly a year ago in a three day seminar. There we had 50 papers and we have published them. Dr. Sharma is preparing the policy document. But when we come to the important question of policy, viz. what should be our energy option for India, we come to a peculiar situation. For power generation in the country, National Hydro Corporation and National Thermal Power Corporation, are the two main contenders because nuclear energy is yet to come up. The demand in 1991-2000 AD according to a paper published by the 13th Power Survey is 1,12,319 MWe. We cannot reach that but definitely we have to step up our energy production. The question is what shall we do? Do we increase thermal or do we increase hydro? Of course, other options would also come up. And somebody pointed out that R & D efforts should be intensified on the non-conventional energy sources. That is a good thing, we may make a breakthrough, we do not know. Nothing is known in science today. It seems to me that the best option would be (of course this is my personal view) to change today's ratio of thermal power to hydro power of 70:30 to 60:40 - 60% thermal, 40% hydel - in the next one or two decades. For environmental protection, it will be better to reduce the expansion of thermal power and increase the expansion of hydel power. And of course, other means should also come up. This should be one of our recommendations. At least I, from the National Academy of Engineering, feel that we have all the options available with us, and all should be used. But the major contenders are thermal and hydro and their ratio should be 60:40. Whatever we talk about, greenhouse effect etc., it is quite true that these effects exist. India is a vast country of 3.4 million sq. km. Since we have abundant rivers and hydro electricity can be generated, not like Narmada Sagar where you have to uproot thousands and thousands of people and which is a big social problem, but in other places we can have a few hundred to a few thousand MW. We should also develop nuclear energy and other sources too.

Dr. Varadarajan (Vice President, INSA): I only want to say that we should address some questions which are related to science policy, apart from options. The Academy has a number of people who can think about science and science policy in relation to energy. Firstly, the outlook for us is extremely bleak. In the next 10 years certainly we will not be able to generate an additional 38,000 MW. We do not have that kind of money. So we are going to have a very serious energy crunch both in the oil front as well as in the electricity front if our present calculations on allocations persist, I am sure and Mr. Satish Chandran would agree.

The second point is that we are not looking at the kind of policies which are related to the development of necessary scientific inputs. Our total research and development inputs into power - electricity generation - may be only 10-20 crores per year (I do not know). That is relatively small money in relation to the total output of electricity. We have even smaller amounts for R & D in transmission control systems. We do not at all have enough research in energy production compared to what we are spending in say atomic energy, which of course is very necessary in the long term. But we are not spending anything at all in other areas. We do not have many institutions and our universities, IITs and so on are very tiny. We have Research and Scientific Committees on power which have no money to distribute. I think it is a very poor show. I estimate that we need to spend at least 500 crores of Rupees a year on various forms of research related to power generation and power transmission.

Our import bill for petroleum is already increasing at the rate of 8-9% per annum in addition to electricity demand which is also increasing at the rate of 8-9% per annum in relation to population rise of 2% per annum and this will continue. Estimates are that if we apply good technologies and good equipment it should be possible to reduce our energy utilisation by about 17 to 19%, For instance our 86 lakh pump sets, I believe, are only about 12 to 14% energy conversion efficient while we can produce 52% efficiency pumps. Yet because of our policies we continue with such situations. It may be cheaper to give efficient pumps free and take back the old ones.

Similarly, we have almost no real institute to study combustion systems. We are spending so much money on burning and yet we have no integrated approach to combustion . There are, in many other countries, institutes of combustion. Our energy efficiency in biomass based energy usage is low and can probably be increased by 4-5 times. Nothing has been done in real terms except amateurish attempts. I do not mind even if you invest in chulas and so on. And I think it should be possible to devise such systems and

give them away, if necessary, to conserve energy, conserve oil, wood and so on.

The convenor Mr. Chidambaram produced very good figures on the differences between developed countries and us. I think it will be very nice to produce a graph on what is happening in rural India, poor India and rich India. All of us are using may be 50 - 100 times as much energy as anyone in a village. I think we should correct ourselves. There should be energy tax on individuals before we put tax on coals, tax on hydro-carbons, carbon dioxide tax, etc. All of us are extremely guilty in the way we use energy which is an extremely scarce commodity and there is not enough consciousness in our media and our schools through NCERT and here, we can do just like for hygiene. Energy awareness should be taught everywhere and a method for this should be found on a priority basis. The risks are very high and the crunch will be very difficult to overcome. Similarly, petroleum conservation is urgently necessary as Mr. Satish Chandran has said.

The other institution we need very badly is an institute for heat transfer. Most of the losses in any energy conversion from one form of energy into another, fuel into electricity, magnetism or mechanical motion, whatever it is, but I think it is known. We do not really have a pooled body for heat transfer, and institute which would be a very important addition, is required.

Lastly, I think the biggest casualty in energy is truth. As Mr. Satish Chandran pointed out it is not intentional but it is because you become attached. I am not saying you are not speaking the truth and everybody thinks he is speaking the truth: atomic energy and non-conventional energy, biogas and so on. The technology analysis and assessment has not been done independently. Safety and environmental impact have not been independently evaluated and that is true of biogas too. Cow-dung, as a fuel is much better than biogas unless we use it as fertiliser in greater efficiency. I believe we need an independent body, not funded by only Government, but by others. It should be able to produce energy policy. Elsewhere, there is the International Energy Agency, the most powerful medium by which the developed countries come together. We have an energy board and an institute in Bombay. But, we need urgently an inter-disciplinary energy policy institute. Its reports should be published just like that of the auditor-general. There should be no secrets. A great deal of openness is required and the amount of ground information that is available is insufficient for us to be able to come to options and the options not for 2020 AD but options for immediate timeframe. The year 2000 is very near to us.

CONCLUDING REMARKS

***Dr. R. Chidambaram,* FNA**
(Convener)

We must now conclude. I must first apologise for limiting it to more like electricity options rather than energy options. This was somewhat deliberate in the sense that I was given only half a day. You would agree that we had very interesting talks. I am satisfied that all of you are still here after 4-4 1/2 hours of pretty heavy stuff which you have been hearing from the various speakers. If I had put in all other energy options—the kind of energy inputs that go into Indian System—starting with bullock carts and firewood etc., which are all important, I would have needed much more time. In fact, in the case of thermal also, we did omit diesel and gas. But it was clear in the talk of Mr. Chitnis that out of 43,000 MWe thermal power, diesel was producing only about 150 MWe and gas was producing 2000 MWe in the year to 1990. So, only because of lack of time we avoided gas and oil, though we could have included that. Now, one thing on which there is consensus is that we are pretty low down, internationally speaking, as far as per capita energy or electricity consumption is concerned and this is surely a reason why we are a poor country. There is no difference of opinion on this and there is a consensus that we must push up our energy consumption quite rapidly. We are not talking about 10-20 per cent increase, we are talking about increase by a factor of 5 or 10, may be in the next 30-40 years, if India has to take its proper place in the comity of nations.

There are limitations on what we can achieve. We have a maximum of only 84,000 MWe of hydro potential as we heard in Mr. Bhasin's talk and much of it does involve submerging of areas to which we all know there is tremendous opposition. So, pushing through any big hydro-electric power project is quite a strenuous job for the people who are trying to build hydro-electric plants, but we should do as much in this direction as is feasible. It is renewable, it is clean and it does provide in addition water for irrigation.

Now, among the sources of bulk power or energy that we have-coal, hydro, and the much younger brother for the moment, nuclear/Coal obviously has to be our major source for quite sometime to come. I think there was the most interesting comment from Mr. Satish Chandran, when he pointed out that waste lands wood is available for rural poor and this is one thing we should clearly keep in mind. It is very surprising that as the personal income

increases for an urban man, the consumption of electricity grows very rapidly and for a rural person it grows very slowly because it is just not available.

We have to have a very clear understanding on whether we have to operate a plant as a base load or a peak load plant. This is one trouble we have even with the nuclear power plants. The nuclear power plants should usually be used at base load. That they are used for fluctuating power generation, puts a lot of stress on those plants and that is another reason why there is a problem in terms of the breakdown of these plants.

I think we take note of the last comment of Dr. Varadarajan that in our document we should emphasise the R & D input that should go into the various energy systems. It did come out in the presentations of Mr. Chitnis when he talked about the things that we should do starting with better coal transportation and coal beneficiation, gasification and so on. Then surely a great deal of energy research needs to be done on non-conventional energy sources. On solar energy, for instance, to make the cost of those photovoeltaic cells much cheaper than what it is now. There are quite a few other things like realistic tariff to make electricity production an attractive thing. For instance, in the case of nuclear energy, the cost that one is allowed to charge is much lower for the Tarapur station. It is only 47 paise because of the cost which was put in at the time the station was built. On the other hand if they let us charge what is allowed to be charged for other stations, that money becomes available for use in building more nuclear or any other kind of plants. So I think an overall better policy needs to be developed both in terms of charging the tariff and also in supplying electricity i.e. making sure that the electricity which is transmitted at one end reaches the other end without being wasted or even being stolen by people who do not pay for it.

Now, in all these there are environmental problems. There is no question that a big ecological impact could be there if you start hydro electric stations. There are questions of pollution-acid rains, green house effect and all that. And in the case of nuclear, I think Shri Kakodkar has already explained, if you know how to run it safely without accidents, nuclear power is clean and it is safe. But very often it comes out in the discussion on the green house effect, we import the sohpisticated environmental concerns of a developed society into a country in which, for instance, children eat food near garbage dumps and I am sure gastro-intestinal problems this would cause to them are more serious than a bit of acid rain or a bit of green house effect or

a bit of whatever else you can think of. I believe this has also come out in several other statements. There is no question that we must protect our environment but we have to balance this concern with a concern for the kind of problems of poverty which this country faces, that only energy production can reduce. We must also pay sufficient and urgent attention to energy conservation a point emphasised by Dr. Varadarajan.

We must look after the economics of power generation. Of course, we must look for resources to build power stations and right now that is what we are short of.

So ladies and gentlemen, we have had a most stimulating afternoon and evening and I thank all the speakers and all the others who have participated in the discussions for making it so interesting. Thank you very much.

VOTE OF THANKS

J.C. Ahluwalia
Secretary, INSA

It is my duty to propose a vote of thanks. Please be assured, I am not going to add my non-expert views, though I feel like adding them because I have been on the hearing end for many hours.

I would like to thank R. Chidambaram for organising this excellent seminar. I also thank the distinguished speakers, Shri Bhasin, Shri Chitnis, Shri Kakodkar, Professor Sukhatme, Shri T.R. Satish Chandran, and Brigadier Narayanan. We must agree that we had an excellent exposition on the various aspects of different energy generating systems, their problems, present status and future plans, cost-effectiveness, the resource crunch, etc. I hope, we shall come up with something containing tangible results and suggestions.

Thank you very much.

BIODATA OF THE SPEAKERS

1. SHRI J.K. BHASIN

   Shri J.K. Bhasin has long experience in the area of power generation. He has served in various capacities at a number of power stations and related Institutions. He was Chief Engineer and Member-Secretary, Western Regional Electricity Board, CEA, Bombay. He was also on the Narmada Control Authority as its Member (Power) and also as acting Chairman. Subsequently he worked as Member (Planning) CEA and Member (Operations) CEA. Currently he is the Chairman of Central Electricity Authority.

   Shri Bhasin is widely travelled and fully acquainted with the international activities in the area of power and has participated in a number of international conferences and other meetings.

   He has a large number of technical papers to his credit.

2. SHRI B.V. CHITNIS

   Shri Balwant V. Chitnis was born on August 1st, 1925. He received the B.E. Degree in Mechanical and Electrical Engineering from the Collage of Engineering, Poona, University of Bombay, in 1947 and the M.S. degree in Power Systems Engineering from the Illinois Institute of Technology (IIT), Chicago, Illinois, in 1952.

   He joined the Tata Electric Companies in 1953 and worked on the Trombay Thermal Power Station Project. He was transferred to the Tata Consulting Engineers in 1967 and is currently their Vice-Chairman & Director-in-Charge.

   Shri Chitnis is a Senior Member of the IEEE and of Power Engineers India and a Fellow of the Institution of Engineers (India). He was a Member of the Panel on Power Planning of the Rajadhyaksha Committee on Power (1978). He is currently Member, Heavy Electrical Development Council; Member, Board of Governors, IIT, Bombay and Member Working Group on Non-Conventional Energy sources & Technologies set up by the Planning Commission.

3. SHRI ANIL KAKODKAR

Shri Anil Kakodkar is currently Director of Reactor Design and Development Group of Bhabha Atomic Research Centre. He has been active on various aspects related to nuclear reactor engineering for more than 25 years. Some of his contributions include design and engineering of the reactor block for 100 MW research reactor Dhruva as also development of a number of systems and components for Indian power reactors. Shri Kakodkar has played a key role in solving a number of problems connected with our power reactors. Currently, he is responsible for special designs and R & D support for our nuclear power programme.

4. PROFESSOR S.P. SUKHATME

Prof. S.P. Sukhatme obtained his Ph.D. from MIT, USA. He is a well known person in the field of heat and mass transfer and has authored a large number of publications and books on the subject. He is the Editor of the *Regional Journal of Energy, Heat and Mass Transfer*. His special areas of interest include solar energy etc. Professor Sukhatme has been Senior Vice-President of the Indian Society for Heat and Mass Transfer.

5. BRIG. M.R. NARAYANAN

Brigadier M.R. Narayanan (Retd.) is presently the Chairman and Managing Director of Central Electronics Limited, Sahibabad, a public sector enterprise under the Department of Scientific and Industrial Reasearch, Government of India.

Brig. Narayanan had earlier been Director (Technical) at Electronics Trade and Technology Development Corporation under the Department of Electronics. From 1980 to 1983, he had been on the Faculty of the College of Defence Management, Secundrabad. From 1985-88, he had been the project director of Plan AREN (Army Radio Engineering Networks), a pioneering project under the Min. of Defence for modernisation of field force communication. During his tenure, the plan AREN was fielded for the first time in the Army exercise -Ex. BRASS TRACKS-4 in January, 1987.

6. SHRI T.R. SATISH CHANDRAN

Shri Satish Chandran (born on April 14, 1929), obtained B.Sc. (Hons.) degree from University of Mysore, Diploma in Electrical Technology from Indian Institute of Science, Bangalore and Diploma in Economic and Social

Administration from the London School of Economics and Political Science. He joined the Indian Administrative Service in 1952 and occupied various positions in Government of Karnataka and Government of India. He was Advisor (Energy) in the Planning Commission (1976-81). He then moved over as Secretary Department of Power, Government of India. After returning to the State in 1983, he was Chief Secretary to the Government of Karnataka until his retirement in 1987. Presently he is Director, Institute for Social and Economic Change, Bangalore.

Shri T.R. Satish Chandran is an Honorary Life Fellow of Institution of Engineers (India) and is the recipient of several honours and awards. He was President, World Energy Conference (1983-86). He has published a number of papers mainly in the area of energy policy.

ENERGY OPTIONS FOR INDIA

Recommendations of INSA Meeting held on April 10, 1991

As a part of its activities to deliberate on topics of national importance involving significant science and technology inputs, Indian National Science Academy organised a discussion meeting to discuss energy options for India on the afternoon of 10th April, 1991. The meeting was convened by Dr. R. Chidambaram. In view of limited time, the meeting essentially focussed on energy options for India in the context of electricity consumption. Other aspects of energy options are expected to be taken up for discussion later.

Electricity is one of the very important inputs in any developed society. Indicators such as per capita gross domestic product, life expectancy at birth etc. show a strong correlation with per capita electricity consumption. The per capita electricity consumption in India is around 250 units as against 5000 units in Western Europe and around 10,000 units in some more affluent countries. Even after accounting for the need for larger energy use in countries with colder climates for the purpose of space heating, it is clear that we have a large gap to fill to achieve the level of economic development which we would like to achieve. While we should certainly not be apeing the development trends of the west, we must augment our electricity generation capacity to fulfill the just aspirations of our large population.

We have been experiencing shortages in terms of electricity production and this has had an adverse impact on our industrial output. A review of the growth of demand for electricity *vis-a-vis* plans for setting up additional generation capacity indicates that we would be living with electricity shortages for quite some time.

Luckily our country is endowed with adequate fuel resources which can be used for generation of electricity. Considering the large demand and the current state of our economy, it is inevitable that our electricity generation strategies in the short term as well as in the long term are based on domestic fuel. Thus it appears that for meeting requirements of bulk electricity generation we will have to essentially concentrate on coal, hydro and nuclear electricity. For meeting partly the needs in rural and remote areas as well as for some urban needs, one could profitably make use of non-conventional energy sources such as solar or biomass. At specific locations where requisite potential exists we should also tap wind and tidal energy. Conservation measures and more efficient production systems should also be given serious consideration as

they could be cost effective in a number of situations such as use of more efficient pumping sets, better installations with lower friction drops etc.

Coal is likely to remain the main fuel for electricity production for the next few decades. In view of the poor and uncertain quality of our coal, a lot of problems are being faced in operation of our boilers. With techniques such as coal beneficiation one can ensure consistent quality coal feed to our power stations. This would not only help minimise the problems being faced but would also mean transporting more energy per unit mass through our railway system which are already overburdened with such transportation needs. While these solutions are not new, there are problems in their implementation and it appears that certain structural changes would be necessary to bring in better coordination between agencies involved in mining, transportation and final use of coal.

There is a global concern these days with regard to problems related to large scale CO_2 production. There is thus a need to bring in greater efficiency of conversion and thus reduce CO_2 production per unit of electricity produced. Advanced technologies such as combined cycle plants, fluidised bed boilers, etc., need to be quickly developed and adopted. There are likely to be international pressures for adoption of global environmental concerns.

We still have considerable hydro potential that remains to be exploited. There are problems related to displacement of large populations in case of large hydro electric schemes. These need to be adequately resolved. We should also give considerable attention to smaller hydro power plants which could help augmenting hydro electricity generation which is very useful for meeting the peak load requirement. At present the ratio of coal power to hydro power has become somewhat unfavourable and there is a need to correct this by adding more hydro electricity generation capacity. It may also be worthwhile to use natural gas for meeting peak power demands in short term. However, in the long run dependence on hydrocarbons for electricity generation cannot be recommended in view of their limited availability and the more urgent need to use them in other sectors such as transport, fertilisers etc.

Long term considerations and the need to secure our energy independence necessitate development of nuclear power so that we can benefit from our natural uranium as well as our vast thorium resources. Nuclear technology operates in a very restricted regime internationally. Fortunately self reliance has already been achieved through domestic efforts in this technology. There is a need to augment nuclear power generation capacity which at the moment

is rather small (around 2.5%). Breeder reactors should be developed to enable full use of nuclear fuel resources. Also we should develop reactors which use thorium.

With regard to non-conventional energy sources, there is a general feeling that we should concentrate on specific areas of interest such as solar (thermal and photovoltaic), wind, biomass and tidal, rather than spreading our resources thin. Although the individual unit generation capacity with these sources is likely to be small in the near future with generation costs somewhat higher, we should pursue these developments since these sources are renewable and provide useful energy in the rural as well as remote areas. There is a need to find solutions to the problems of maintenance of such systems since they are located far away from industrial infrastructure and services.

While we have to be fully conscious of environmental concerns and find solutions to keep environmental impact from the power plants to a minimum, we must also be conscious of the need to alleviate poverty which, apart from being our most important problem needing an urgent solution, is the greater pollutant. Considering the electricity consumption pattern in the country, where the consumption by the middle class is demand-saturated rather than supply limited, the addition of new electricity generating systems may reach the poorer sections of the society more effectively. We must give high priority and generate as much electricity as possible based on available technology, trained man power and financial resources without worrying too much about realising an optimal mix. Maximisation of energy generation should be our top most priority in the short term.

There is a need to considerably augment research and development in areas related to energy tecnologies. The allocation for sustaining such R & D systems should be assessed and planned such that we do not have to depend on foreign countries for future technologies that we may need. Efficient coal technologies, nuclear technology, solar technology are some of the areas that should be viewed with priority. There is also a need to sustain R & D programmes in some basic engineering areas related to these technologies. Combustion, heat transfer and fluid flow, materials development, are some of the areas that need attention in this regard.